A NEW SYSTEM OF ASTRONOMY,

UPON AN IMPROVED PLAN.

WHEREIN THE
SCIENCE OF OPTICS IS FULLY INVESTIGATED,

AND THE
LAWS OF REFRACTION EXAMINED AND EXPLAINED.

Rectifying many errors with respect to the distance of the sun and planet stars, from the earth, and one another, shewing from whence the mistakes have arisen.

LIKEWISE,
Treating upon the different elements; of winds, rains, hail, mist, dew, &c. of the flowing of fountains, streams, and rivers; and of the ebbing and flowing of the sea.

By JOHN FLEMING.
K

The works of the Lord are great, sought out of all them that have pleasure therein. Psal. cxi. 2.
The heavens declare the glory of God: and the firmament sheweth his handy-work. Psal. xix. 1.

GLASGOW:

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M.DCC.LXXXVI.

To his GRACE

DOUGLAS,

Duke of Hamilton, Brandon, and Chattelherault.

May it pleaſe your GRACE,

AMONG all the ſciences which have been continually improved, and are daily improving in the world, the firſt place has, by the general conſent of mankind, been always given to Aſtronomy. And ſuch has been either the good fortune of this ſcience, or the virtue of mankind, that the greateſt and moſt eminent perſons in all ages and nations, have been patrons and encouragers of this ſtudy.

Of all the ſciences cultivated by mankind, Aſtronomy is acknowledged to be, and undoubtedly is, the moſt ſublime, the moſt in-

tereſting, and the moſt uſeful. By it our very faculties are inlarged with the grandeur of the ideas it conveys; and our underſtandings clearly convinced and affected with the conviction of the exiſtence, wiſdom, power, goodneſs, immutability, and ſuperintendency of the ſupreme Being.

By this branch of knowledge, we learn by what means, or laws, the Almighty carries on, and continues the admirable harmony, order, and connection, obſervable throughout the planetary ſyſtem; and are led by very powerful arguments, to form the pleaſing deduction that minds capable of ſuch deep reſearches, not only derive their origin from that adorable Being, but are alſo incited to aſpire after a more perfect knowledge of his nature, and a ſtricter conformity to his will.

In order that the reader may underſtand Aſtronomy more perfectly, I have treated upon the ſcience of optics; of the nature and manner of refractions, and that not only of the viewing of objects within our atmoſphere properly, but alſo of the viewing of luminous

bodies beyond our atmoſphere, in the ethereal heavens. And I have, by the order of the refraction of the air, ſhown how that re-refraction operates differently upon the ſun, moon, and ſtars, in the firmament of heaven, according to their reſpective diſtances, in raiſing them and keeping them in view, when at the horizon, juſt in proportion according as they are near, or more diſtant from the obſerver on the earth. I have alſo given diagrams for demonſtrating the time of a planet's paſſing over the meridian, within four minutes of time, throughout the whole period, which no ſcheme of Aſtronomy has hitherto done.

I have alſo treated on the four different elements, as to their nature and qualities; and of the various meteors in the air, ſuch as winds, rains, ſnow, hail, miſt and dew. Together with the cauſe, order, and manner of the flowing and running of fountains, ſtreams and rivers on earth; and likewiſe of the ebbing and flowing of the ſea. And ſhew how far this movement of the ſea de-

pends upon the motion of the ſun, or moon, in the heavens, and how far not. And have ſhewed how all theſe things are under the direction, management and control, of the wiſe powerful providence of God, the author and governor of all things in the world, animate and inanimate.

I dedicate this book to your GRACE, as you are a lover of learning, and ſkilled in the mathematical ſciences, of a lively genius, and quick penetration. And whatever may be in the author or the work, to recommend it to your favour, will abundantly be ſupplied by the dignity of the ſubject.

And although the diſtance of the heavenly bodies, as here given, be much leſs than it is reckoned to be by ſome Aſtronomers; becauſe the Copernican ſcheme of Aſtronomy ſuppoſes the heavenly bodies to be a hundred times more diſtant from the earth than they really are, and conſequently their ſuppoſed magnitudes differ much from the truth. On the hearing of this, ſome of the preſent Doctors and teachers of Aſtronomy, upon the

Newtonian principles, made a ſerious and ſolemn appeal on the ſubject to the future ſtate, where the true ſtate of things will be perfectly known. As to this, it is nothing but a regard to the intereſt of truth, when proper inſtruments are employed in finding out the diſtance of the heavenly bodies, that induced me to publiſh this abridgment.

It was partly for the ſervice of the fair ſex, and particularly for the ſervice of her Grace, the DUTCHESS OF HAMILTON, who is of moſt amiable endowments, that I have publiſhed this work. It is but juſtice to the ladies to ſay, that ſuch of them as delight in Arts and Sciences, as to quickneſs of perception and delicacy of taſte, are equal, if not ſuperior, to men. And it is no diſparagement to the ladies to ſay, there is not a finer genius than my LADY DUTCHESS.

May all the luminaries in the heavens ſhed their kindeſt influences on both your heads; and may you long continue to enjoy the affluence of all happineſs on earth, and at laſt come to enjoy the more ſublime plea-

ſures which are in the celeſtial regions above, is the deſire of

Your GRACE's

Moſt obedient,

And moſt humble ſervant,

JOHN FLEMING.

NOOK of Eaſt Kilbride, near Glaſgow, May 27th, 1786.

ADVERTISEMENT.

THE Astronomer that desires to find the Sun and Moon's distance, whether from his own observations, or that of others, the lines of the Apparatus he uses for this purpose, may be fifty yards long, the larger the better; and making a curve in the line at that point of the air where they are seen to touch at their setting, of 34 minutes of a degree for the horizontal Refraction; then lengthen out this line to a section of the Moon's orbit, and also to a section of the Sun's orbit. And when this is done, it makes a proper foundation for a calculation of the Sun and Moon's distance from the Earth.

Also, the learned Reader, when viewing the Copperplate Figures in the book, together with their explanation of the Planets' motions in the heavens, may lay before him an Astronomical Table of the periods, revolutions, magnitudes, mean distances, excentricity of the orbits, and place of the Aphelion points of all the Planets. And particularly when reading the explanation of the Tropical periods of Saturn and Jupiter, and viewing their Copperplate Figures, he may lay before him Dr. Edmund Halley's Tables of these Planets, for the periods mentioned in the book. Likewise, when reading the explanation of the Apogeon and Perigeon periods of Saturn and Jupiter, together with their nine Satellites, and viewing their Copperplate Figures, he may lay before him Monsieur De La Callie's Astronomical Tables for the periods as mentioned

in the book, and then he will ſee with his own eyes the juſtice that the Author has done in conſtructing his Copperplates for that purpoſe.

This takes off the erroneous and enormouſly great diſtance that the Sun is ſuppoſed by ſome to be at from the Earth; and alſo explains the Cycles and Epicycles, and the excentric Circles of the Ancients; together alſo with the ORRERY and the Ellipſis, the Apſides and excentric Focuſes of the Sun by the moderns, which has much perplexed the Philoſophers, in all ages, to underſtand.

The Copperplate Engravings in this work give the place of the Planets, in their different periods and orbits, all round, both as ſeen from the Earth and Sun in one view, in a plain, regular and diſtinct method, giving the reader a certain proſpect of the heavenly Bodies at once, in their revolutions.

THE PREFACE.

AMONGST the ſeveral gifts and benefits which the moſt bountiful God has plentifully beſtowed on mankind, theſe are in the firſt place valuable which conſiſt in the improvements of the mind, by Arts and Sciences. And among the ſciences there are none which Aſtronomy comes behind, upon account of its antiquity, and the pleaſure that attends the ſtudy of it. Aſtronomy is in itſelf one of the profoundeſt and moſt intricate of all the ſciences, and of the greateſt difficulty of acceſs into its myſteries; yet to a man whoſe genius is properly adapted for that ſtudy, and who is equipt with proper inſtruments for his purpoſe, it is one of the moſt pleaſant ſtudies in the material world, and has in it a kind of attractiveneſs in drawing forth the faculties of the human mind.

To ſee a regular ſucceſſion of day and night, a conſtant return of ſeaſons, and ſuch an harmonious diſpoſition and order of nature, muſt neceſſarily be a noble contemplation, and agreeable to the nature of man.

There have been great contentions among the learned of different nations, about the origin of this ſtudy, every one claiming an intereſt in it, as the Babylonians, Egyptians, Grecians, Scythians, &c. And for ſeveral centuries paſt, it has been much ſtudied and improved in Europe.

By Aſtronomy, we come to diſcover the wonderful harmony of nature, wherewith the frame and ſtructure of all created beings are linked and knit together, to conſtitute the great machine of the univerſe. It teaches us to obſerve and diſcover the motions of the

heavenly bodies, and it confiders the vigour and force by which they circulate in their orbs. It is a fcience which the greateft heroes from the beginning of the world have taken pleafure to ftudy and improve; fo that it was always efteemed as a fcience fit for kings and emperors to employ themfelves in. On which account the Chaldean wifemen and philofophers, were always reverenced and favoured by the ancient kings, who thought it abfurd that any fhould govern the world, who knew not what the world was.

The excellency of this fcience appears from this, that there is no knowledge which is attained by the light of nature, that gives us truer and jufter notions of the fupreme Being, the maker of the Heaven and Earth, than it does. No fcience furnifhes us with ftronger arguments by which the excellence of God is demonftrated. Nothing fhews more his power and wifdom, than the contemplation of the Stars, thefe heavenly bodies, and their motions. King David, that holy Prophet, tells us, that "The Heavens declare the glory of God: and the Firmament fheweth his handy-work." And alfo, "The Heavens declare his righteoufnefs, and all people have feen his glory."

Marcus Tullius Cicero, who was guided only by the light of nature and of his own reafon, had the fame fentiments alfo. "Nothing," fays he, "is more evident, nothing plainer, when we look up to the Heavens, and contemplate the bodies there, than that there is a Deity, of moft excellent wifdom who governs them." What is there that more ravifhes the mind of man into admiration, reverence, and love of God, than fo many and fo great bodies endued with heavenly light, and moft beautiful to the eye; and

when contemplated, moſt delightful to the underſtanding. Their mutual intercourſes, moſt regular motions, their certain and determined circulations and periods, ſettled by the divine law, in an admirable harmony, make manifeſt to us the immenſity of the power, wiſdom, and providence of their Almighty maker and preſerver; which, when we conſider, we muſt neceſſarily acknowledge and reverence the author and governor of all theſe things.

As the Heavens declare the glory of their divine Author, ſo alſo, is the Earth full of the riches of his goodneſs, which is compoſed of different Elements, and of their different qualities, fully adapted for the uſe and benefit of mankind and other creatures upon it.

In the following work I have given the order of the Heavens, and the motion of the Sun, Moon and Stars, according to their viſible appearance in the Firmament of Heaven, from eaſt to weſt; together with the relative circulation of the Planet-ſtars about the Sun, in their different periods, from one oppoſition or conjunction to another. This I have done very particularly, in giving ſeveral examples: by ſhewing both Saturn and Jupiter's paſſage through all the Signs of the Zodiac, together with their Nine Satellites along with them, and their different anomalies and equations, and manner of appearing in the Signs from one apogeon to another, according to the exact deſcription of theſe excellent tables, done by Dr. Edmund Halley, and Monſieur De La Callie, which ſhew the place in the Heavens of theſe Eleven bodies, by the figures I have made for any given time, during the periods which they comprehend.

But I have not given the regular courſes according

to equated times of Mercury, Venus and Mars, thro' the Signs of the Zodiac, as I have done of Saturn and Jupiter, with their Satellites; I have given only their mean motion, becauſe theſe three Planets move more rapidly thro' the Signs, in the time between one conjunction and another, than Jupiter and Saturn do. Their uniform regular courſes may be delineated on moveable figures, but cannot be deſcribed upon fixed figures as Saturn and Jupiter's are.

I have not inſerted Dr. Halley, and De La Callie's tables, in the following abridgement, for ſwelling the book too much, for the curious reader will ſee the quotations juſtly taken which I have mentioned, by looking into the tables themſelves.

The eſſay which I have made upon the Sun's diſtance, and conſequently of all the Planets', is taken from the Moon's diſtance from the Earth, by ſhewing the nature and manner of Refractions. The inſtruments made for ſhewing the refracting power of the Air, make it manifeſt, that the Sun cannot be much more than ſix times more diſtant from the Earth than the Moon is from it, according to the true times we ſee them riſe and ſet in the Horizon. When the Moon ſets in the Horizon, there is allowance made of about 34 minutes of a degree for the refraction, which cauſes the Moon's centre to appear 34 minutes above the Horizon, when her centre is really in it, and the Sun being always under the power of refraction as well as the Moon. If the Sun were near 400 times more diſtant from the Earth than the Moon is (according to the opinion of ſome men) he would be ſeen floating in the Horizon near half an hour after ſix at night, when he is in the Equator; whereas, it is manifeſt to all men, that the Sun ſets

very near at ſix o'clock, when he is at the Equator.

I have alſo demonſtrated the ſame thing, from the obſervations of the Tranſit of Venus, over the Sun's diſc, in the year 1761; and Ariſtarchus's method for finding the Sun's diſtance, by taking the biſection or true dichotomy of the Moon in the quadrature. When all things relative thereto, are conſidered in it, theſe will ſhew, that the Sun is near the diſtance from the Earth that I have mentioned. For the exhibiting more fully, the obſervations of the Tranſit of Venus over the Sun's diſc, and to ſhew the quantity of Refraction, that the Sun and Venus were under, when the obſervations were taken, I made a Quadrant of ninety feet radius, to ſhew theſe Refractions; and when proper allowance was made for them, I had the Earth's parallax to within two ſeconds, given by the inſtrument, and made as plain as demonſtration can make it, that the Sun cannot be much more than ſix times the Moon's diſtance from the Earth.

But what I am obliged here to obſerve is, the inconſtancy of the Refractions every where, and even the precariouſneſs of the tables that are given of the Refraction. The Refractions are conſtantly known to vary, thro' the denſity of the Air ſtill varying. And the exact juſtneſs of the tables of Refraction cannot be depended upon at any time, in a matter of ſuch Nice diſcuſſion, as the finding of the Sun's diſtance from the Earth; or which is the ſame thing, to find the Sun's Horizontal parallax. This I hint to my learned readers, becauſe I find upon different trials, that theſe tables are not altogether to be truſted. And as is the certainty or the uncertainty of the quantity of Refractions, ſo is the certainty of the Sun's diſtance

from the Earth. However from the moſt certain demonſtrations, I find that the Sun is by a great deal too near the Earth, for the Earth and Moon to go round about the Sun in a year, as is ſuppoſed by ſome, according to the courſe they have, and the appearances they make in the Heavens.

And as the principal deſign of the following work, is to ſhew the harmony that there is between the word and works of God, I have brought up a number of paſſages of Scripture, to ſhew that the Sun, Moon and Stars, circulate round about the Earth, in the firmament of Heaven, and that the Earth is fixed unmoveable in the centre.

The work alſo treats a little upon the nature, qualities and operations, of the different Elements of which the world is compoſed. As the Heavens declare the glory of their divine Author, ſo the Earth is full of the riches of his goodneſs. Who is it that contemplates this admirable frame of the world, and therein the Sun, Moon, and other celeſtial bodies, conſidering their moſt bright light, moſt powerful faculties, ſundry turnings and returnings, and yet for ſo many ages ſo certain and regular, but that he muſt needs acknowledge a moſt wiſe and almighty Creator? Who that views this vaſt region of the Air, and the clouds therein flying and hanging over our heads, and the rains, ſnows, hails, thunders, and other meteors? Who that weighs and ponders in his mind this globe of the Earth whereon we tread, hanging by Geometry in the empty Air, and thereon the high mountains, ſteep hills, low vallies, plain fields, and theſe beſet with ſo many trees, ſhrubs, herbs, flowers and fruits, affording food for ſo many ſorts of living creatures? So many foun-

tains, brooks, rivers, and the ſeas themſelves, and in them a countleſs crowd of fiſhes; and in the Earth's bowels ſo many ſorts of minerals, mines, and metals, all kept in order and regularity? Who, I ſay, that ſees and conſiders all this, without admiring the wiſdom, and almighty power of God, the maker of all things, whom St. Paul himſelf, in the firſt chapter to the Romans, thus writes: "The inviſible things of God are "clearly ſeen, by the creation of the world, being "underſtood by the things created, namely, his eter-"nal power and Godhead."

What I have wrote and demonſtrated upon the laws of Optics, one part of it may be eſteemed ſo plain and eaſy, that every writer on that ſubject knows it very well already, and ſo there was no need for writing upon it. For who is it but knows, that when the rays of light falling upon glaſs, water, oil of turpentine, &c. the ray is turned out of its ſtraight courſe, and appears as if broken and bended at the point of incidence, between the rarer and denſer medium? And another part of it may be eſteemed abſtruſe, and not eaſy to be underſtood. For altho' we know the laws of viſion, within the Air that ſurrounds the Earth, yet it is more difficult to know the laws of viſion, when they paſs thro' our Atmoſphere into the ethereal Heaven.

The good reader will pleaſe indulge me in an apology, for writing upon both theſe parts of Optics; both on that part, which treats on viſion in viewing objects here on Earth, and the other part of it, which delineates how the rays of light are directed to us from the Luminaries in the ethereal Heaven, through the Atmoſphere to us here on Earth. The firſt part explains the ſecond; and they conſiſt together in this,

that no ray of light comes to us on Earth, from any of the Luminaries in the Heavens in a ſtraight line, except from the Vertex or Zenith, and this in ſuch a manner, that if the Sun and Moon in conjunction, in their true place, were in our Zenith, as they are ſome times to thoſe under the Equator, the ray would be directed to the Earth in one ſtraight line; but in no place of the Heavens hence, nearer the Horizon.

For if the Sun and Moon were in conjunction in their true place in the Horizon, the Sun would be ſeen in a line in the perpendicular above the Moon's body, at a conſiderable diſtance above it, ſo much, that he would be more than a quarter of an hour longer in ſetting than the Moon, by means of the Horizontal Refraction; that is to ſay, if the Sun were four hundred times more diſtant from the Earth, than the Moon is from it. Therefore, when we draw figures, ſhewing the proper quantity of the Horizontal Refractions, and delineate the Earth's diſc, the Moon, and Sun's diſtance from it, all in their due proportion, as when they are ſeen at ſetting in the Horizon, we are obliged to bring the Sun's orbitual ſetting in the Horizon, within little more, in or over, than ſix times the Moon's diſtance from the Earth. And near at ſaid diſtance, the Parallaxes and Refractions of both the Luminaries balance one another, in ſuch manner, as brings them to ſet exactly, at the time that they are ſeen by all men to ſet, when they are at the Equator.

As this ſolves a problem the moſt important, and the moſt curious in natural philoſophy, I will therefore, that the learned reader, before he write upon the order of the heavenly bodies, that he take care how he finds out the diſtances of their Orbits. And I here

let him know, that this cannot be done by a calculation alone, as has hitherto been tried by many, without proper effect. But let him delineate the Earth's disc, and the Moon's orbit in due proportion and distance, with a proper quantity of horizontal Refraction to the Moon's orbit, at her setting, which is a work that can easily be done; then let him go back with the Sun's refracted Ray, behind the Moon's orbit on the figure, as far as he pleases; and if the Sun's Ray have the same quantity of horizontal Refraction with the Moon, he will then know where to draw the Sun's Orbit upon the figure.

And as bodies appearing under the same angle, increase in bulk, in a subduplicate proportion to their distance from us: to suppose the Sun at 400 times more distance from the Earth than the Moon is, would increase the Sun's bulk 1000 times greater than the bulk which he appears to have, at the distance which we have calculated him to be under.

As to the Pneumatics, in what is wrote upon the nature and properties of the Air, in the following work, it is taken from its effects, as observed under the Frigid Zones, where its qualities are not intermixed with the qualities of other Elements, so much as under the Temperate and Torrid Zones. Under the Torrid and Temperate Zones, the Air is so impregnated with heating causes, that its cold quality cannot so easily be found out, as under the Frigid Zone, where little or no heating causes affect it, to alter its natural quality.

All material bodies are understood to be either in motion or at rest. And that they are put and kept in motion, answers all the purposes of the animal creation, and even of vegetative life itself, which could

not be ſuſtained without the regular motion of the Elements and heavenly bodies. Now there are two ſimple motions, the right or ſtraight, and the circular. The circular belongs to the heavenly bodies, and therefore the ſtraight motion, we attribute to the Elements.

As to that hypotheſis which ſuppoſes that the heavenly bodies have a projectile motion impelled on them, to move in ſtraight lines; and an univerſal power of attraction, which draws them off from theſe lines, which form the circular motions of the heavenly bodies. This hypotheſis is not altogether conſiſtent with itſelf, and affords us but very little light in this matter. And we hold that the heavenly bodies are moved by a power, and faculty implanted in them by God their creator, without any violent and external impulſe or carriage. For that God who willed and commanded, that the Sun, Moon and Stars, by their motions, that they ſhould deſcribe the times, days and years, gave them power likewiſe to effect their different circulations. And if the Creator could put ſuch power into the Elements of Earth and Fire, that in a moſt ſtraight line the one ſhould move down to the centre of the world, and the other upwards from the centre, why could he not give the Luminaries in the Heavens, ſuch a power as to move circularly?

The admirable traces of an infinite wiſdom and power, which we diſcern in the formation of the Elements and various bodies in the viſible world, are ſuch a proof of a Deity, that a man may as reaſonably doubt whether he exiſts himſelf, as call in queſtion the being of a God. Now next to the acknowledgement of a Deity, is the owning that the ſame excellent Being governs the world; for there is a neceſſary connection betwixt the belief of a God and a

providence. It is as unreaſonable to think that all things in this world happen by chance, as to affirm that a fortuitous concourſe of atoms ſtretched forth the heavens, and laid the foundations of the earth.

As the power and wiſdom of an inviſible Deity, are manifeſted by the things that are made, ſo are the ſame perfections wonderfully diſplayed in the government of the ſame things. One branch of which divine adminiſtration conſiſts in preſerving the creatures that are formed, and it being impoſſible they ſhould have any principle of ſelf-ſubſiſtence independent on their firſt cauſe; for it is incompatable with the nature of a creature to be independent. Now, as the unlimited power of God, is neceſſary to uphold all things, ſo is his infinite wiſdom to direct and guide them. It is not ſullen fate, nor giddy chance, but a wiſe and powerful Deity, that holds the reins of government of all the elements and bodies of the world, which are under the wiſe and powerful management of Heaven.

I was ſome time in abridging the following work, from my large manuſcript, in which I have been as conciſe, as I could do it with perſpicuity, both for finding out the true diſtance of the Sun, Moon and Stars, and alſo the order by which they move in the Heavens. The method I have taken in finding the diſtances of the heavenly bodies, is by exactly following the laws of nature, and the order of their courſe in the firmament of Heaven which I have given, is in conformity to the moſt exact Aſtronomical tables which we have extant. In which I have been happy in finding the order and motion of the heavenly bodies, agreeable to divine revelation in the Holy Scriptures; and likewiſe, ſuitable to the inclinations and common ſenſe of all men. And notwithſtand-

ing all the books wrote upon Aſtronomy, that are extant, one compoſed upon the principles that this abridgement is made upon, is abſolutely neceſſary to come at the true knowledge of the ſituation and order of the material heavens.

After all the curious obſervations we have made, upon this grand and ſtately theatre, contained within the canopy of theſe viſible and material heavens, the great uſe we are to make in our contemplations of them in our militant ſtate, is to ſhew forth the praiſes of that God, who made and upholds them in their nature, number and order. And that the reader may be admitted to do it, in a more exalted manner in the triumphant ſtate, through the intervention of the great Surety of the well-ordered covenant, is the earneſt deſire of

J. F.

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ERRATA.

Page 38. line 30. read rendered for hindered.
74. in the contents of chap. xvii. read obfcurations for obfervations.
77. line 24. read obfcured for obferved.
82. line 27. read Sun's difc.
104. line 3. for 2 read 9.
104. line 19. read as.
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125. line 31. read Venus near two times.
155. line 8. read fome.
190. line 17. read element.
196. line 4. read it.
198. line 24. read unmixed.

A NEW SYSTEM OF ASTRONOMY.

CHAP. I.

Of the nature and manner of Refractions, ſhewing that when the rays of light, from a luminous body, fall upon a medium of a different denſity from that from whence they proceeded, they do not afterwards go on in the ſame ſtraight lines.

BY the laws of optics, in the viewing diſtant objects, it is neceſſary to know the medium thro' which they are ſeen, in order to know either their magnitude or their elevation. All the heavenly bodies are viewed through two different mediums; the one more rare, and the other more denſe.

In reviewing the heavenly bodies, the ray comes from them through the ethereal air much more rare than ours, or rather from near a perfect void; and then falls on our atmoſphere, which is denſe in com-

CHAP. I. parifon of it. And as we view the fun, moon and ftars, in the concave femicircle of the heavens, it is the caufe why we fee them fometimes in their true place, and fometimes above it. And the more or lefs fo, according to their refpective diftance from us.

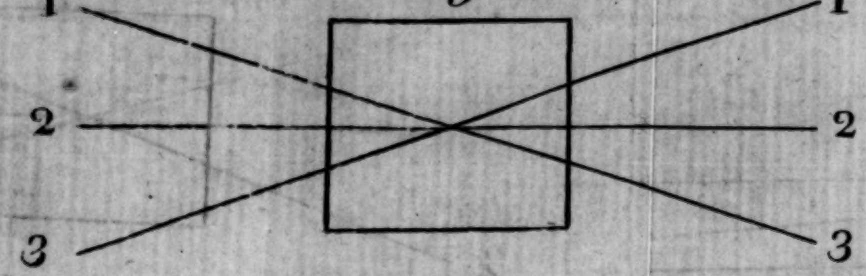
And this is what the learned reader is to take notice of, and bear in mind for the underftanding of this chapter, that we view all the heavenly bodies in the higher femicircle of their orbits, and through a medium of air that is convex above us; which is the caufe that thofe bodies in the heavens, which are at a greater diftance from us, are much more elevated above their true place, than thefe that are nearer us, when they are both in the horizon. This is what due confideration will very eafily inveftigate; and is the fubject treated of in this chapter.

A ftar in the vertex or zenith has no refraction. For a perpendicular ray goes ftraight on; but the more obliquely the ray falls upon the furface of the air, fo much greater is the refraction; fo that the horizontal refraction is the greateft of all. And the ftars are longer feen in the horizon above their true place, than the fun or moon are; and the fun is longer feen in the horizon than the moon, upon account that the fun is at a greater diftance from the earth than the moon.

And it even happens, that the ftars which are below the horizon, may be feen above it. This is the caufe why the two great luminaries, the fun and moon, when one of them is above the horizon, and the other below it, may both appear above the horizon: fo that the moon has been obferved eclipfed when fhe was below the horizon, and the fun above it.

PLATE I

Fig: 1.



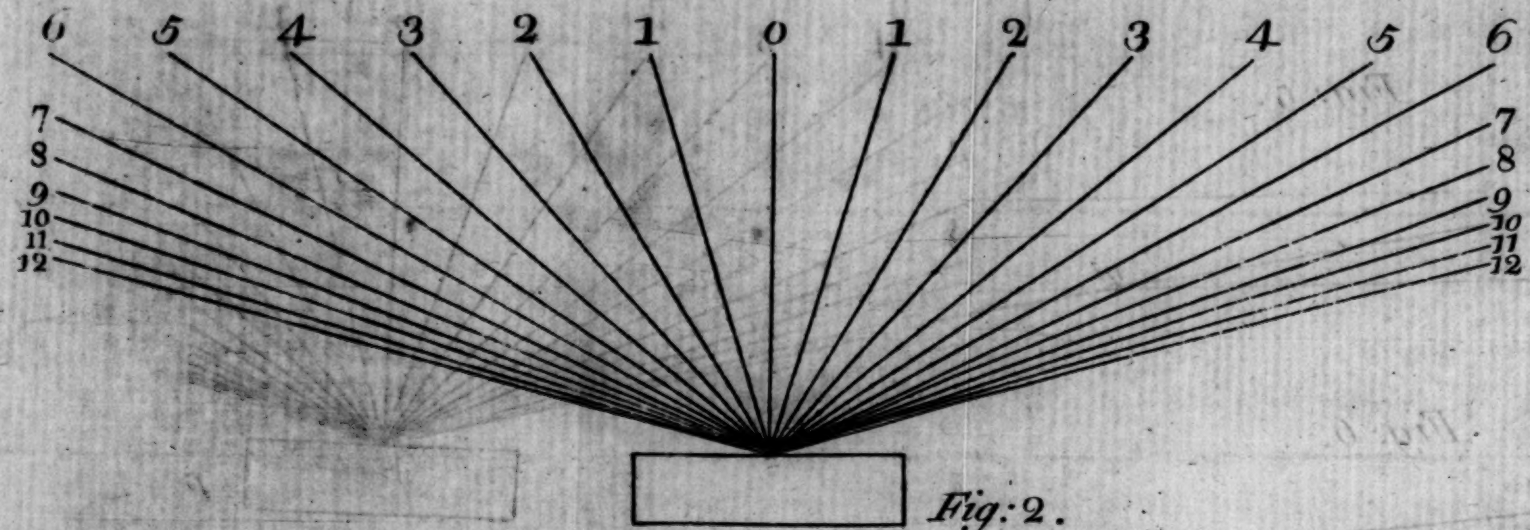


Fig: 2.

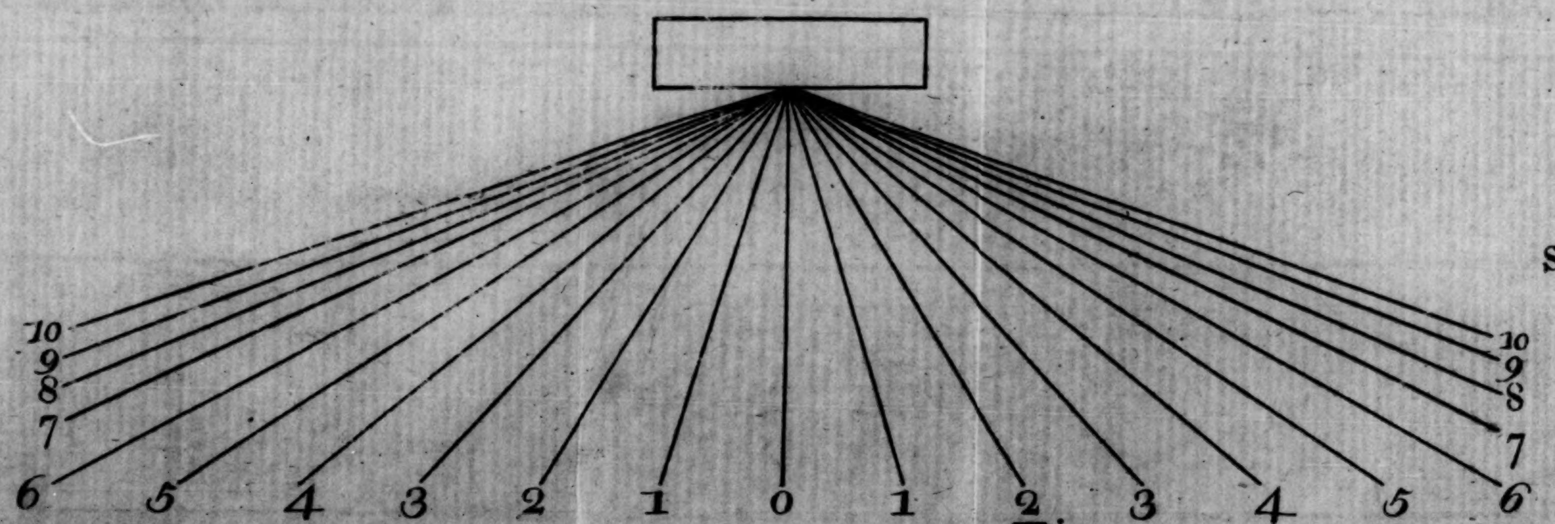
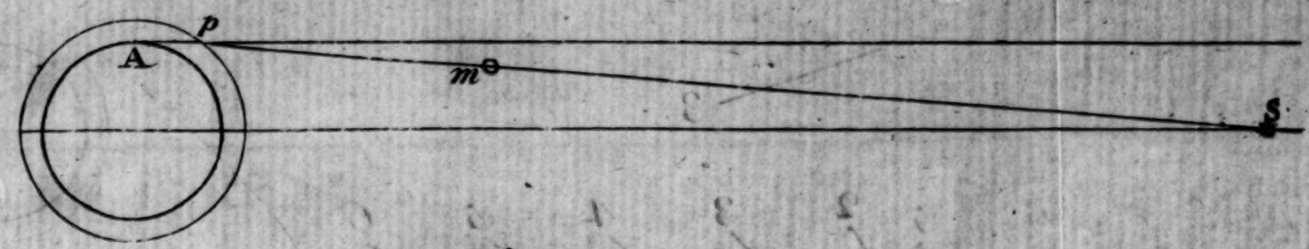


Fig: 3.

Fig: 4.



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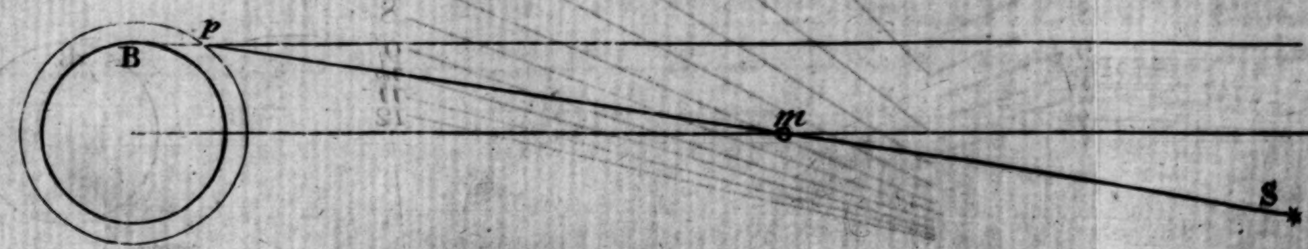

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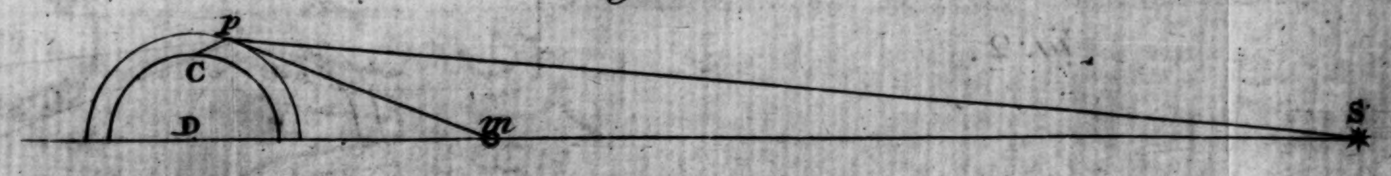


Fig: 7.

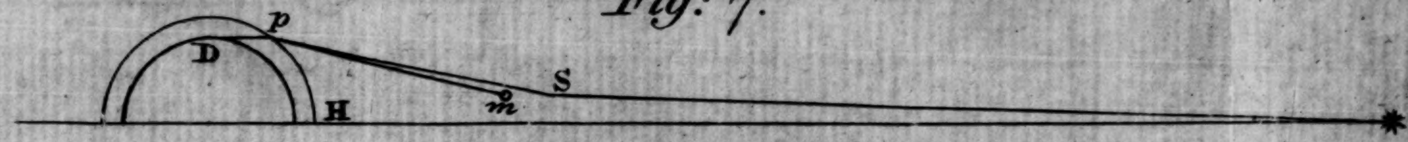


Fig: 8.

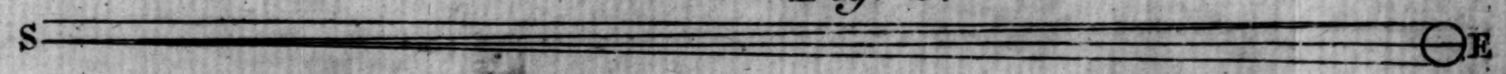


Fig: 9.

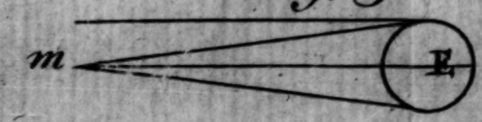
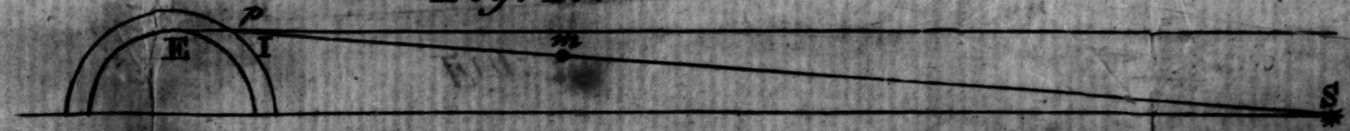


Fig: 10.



CHAP. I.

This is a matter of importance in ſcience, that we ſhould not neglect or overlook any means of help which nature and inſtruments, conſtructed upon proper principles, give in ſolving a problem ſo neceſſary, as that of determining the ſun's diſtance from the earth near to the truth.

By manifold experiments, we find that the rays of a luminous body, even of any viſible object, when they fall upon a medium or diaphanous body, as air or water, of a different denſity from that from whence they proceeded, do not go afterwards directly in the ſame ſtraight lines; but are broken or bended, and propagated as if they had proceeded from another point than they really did. And if the medium be denſer on which the rays fall than the firſt, they are bent towards a line perpendicular to that ſurface whereon they fall at the point of incidence; but if it be a rarer medium, in their bending they recede from the perpendicular. This is what the writers upon optics call refractions.

We ſhall here only give examples of three different kinds of refractions. Firſt, when the refractor (ſuch as a mirror of glaſs) is placed perpendicularly, and receives and reflects the rays horizontally. Secondly, when the refractor, ſuch as a round or ſquare veſſel placed horizontally, and being filled with water, reflects the rays upwards. And thirdly, when the refractor (ſuch as a mirror of glaſs) is placed horizontally, and reflects the rays downwards.

As to the firſt of theſe kind of refractors, Let fig. 1. repreſent a mirror of glaſs as placed perpendicularly, with the one edge upwards, and the other downwards, and it is the nature of this kind of refractors to reflect the rays horizontally, by all different Plate 1. Fig. 1.

CHAP. I.

kind of angles. For if the ray come from the 1 figure, it will be reflected to figure 3; but if the ray come from the 2 figure it will be refracted to figure 2; and if it come from the 3 figure, it will be reflected to figure 1 on the oppoſite ſide of the refractor.

As to the ſecond of theſe kind of refractors, Let figure 2 repreſent a ſquare veſſel filled with pure water to the brim, and it is the nature of this kind of refractors to reflect the rays upwards, and by all different kind of angles. If the ray come perpendicularly downwards upon the refractor from o it will be reflected perpendicularly upwards to o again; but if the ray come from figure 1, on the right ſide of the diagram, it will be reflected to the 1 figure on the left ſide of it; and if the ray come from figure 2, on the right ſide, it will be reflected to the 2 figure on the left ſide of it; and if the ray come from figure 3, on the one hand, it will be reflected to the 3 figure on the other hand: and ſo on through all the oppoſite and correſponding figures in this diagram, until it comes to 12, or the two loweſt rays or lines. And we ſee that theſe two loweſt lines doth not turn the rays ſo much out of their rectilinear courſe as the lines at the figures 1 and 2 doth.

Plate I. Fig. 2.

And as to the third of theſe kind of refractors, Let figure 3 repreſent a glaſs mirror fixed horizontally unto the upper flooring of a room, or otherwiſe, ſo as it will reflect the rays downwards, and this alſo will reflect the rays by all different angles. And firſt place perpendicular below this mirror, a candle, or even any viſible object, at o, and the ray will be reflected perpendicularly downwards again to o; and if the candle be placed at the 1 figure at the

Fig. 3.

right hand, it will reflect the ray to figure 1 on the left hand. Again, if the candle be removed to the 2 figure, on the right hand, its rays will be reflected to figure 2 on the left hand side: and so on in like manner through all these lines 3, 4, 5, 6, 7, 8, 9, until it comes to 10, and highest of these lines, where the ray is reflected by a less curve, than at the figures 1, 2, 3, and so comes nearer to a straight line.

In all these three different diagrams the rays of any luminous or visible body may be seen under all different directions, from the perpendicular at o, where the reflection returns back in the same direct line with that in which it came, until the figures 10 and 12, where the lines are more straight, and the ray comes with a less curve from the place of incidence, and the lines may be made so near a straight that the rays will not be turned above a degree out of a rectilinear course by the refractor.

And if you take a vessel, such as is represented by figure 2, and fill it brim-full of water, and set it in an open space where a person can see the sun rise and set at a considerable distance; then, take the morning of a clear day, and when the sun rises he will just touch the water at the brim of the vessel; but you must hold your head so low, on the opposite side of the vessel from the sun, that your eye be almost level with the surface of the water; and then you will see the ray of the sun as by the 12th line of this figure. And as the sun rises by degrees till noon, you must hold your head higher in proportion, before you see the rays of the sun from the surface of the water. And in like manner, in the afternoon, until sun set, and then he will just touch the water at the brim of the vessel as in the morning.

CHAP. I.

As the veſſel repreſented figure 2, bends and turns the ſun's rays upwards; ſo a mirror of glaſs, as is repreſented by the 3 figure, may be fixed up horizontally over-head in the open field, as to reflect the ſun's rays downwards: and this is done in the morning, or evening, when the ſun is near the horizon, and this is repreſented by the lines 9 and 10 of this figure, which gives a ſmall emblem of the refracting power of the air on the ſun or moon at morning or evening.

What we have hitherto ſaid upon refraction from theſe figures, the meaneſt writers upon optics very well know. But what we intend chiefly here (in order to make way for the following demonſtration) is to conſider that when the rays of two luminous bodies run in the ſame direct line to the refractor, how they are reflected from the place of incidence. And here it is to be obſerved, that if a candle or torch be placed directly at the end of one of theſe lines, and another at the middle of it, or run along the ſame line backwards or forwards at pleaſure, they will touch at the ſame focus, and be obſerved to do ſo by a ſpectator at the end of the correſponding line from the place of incidence; and the rays of both theſe two lights will run in one line, and be ſeen by inſpection at the end of the correſponding line throughout all the angles of the different lines in theſe figures, which is found to be ſo by experiments. But more of this afterwards.

CHAP. II.

CHAP. II.

Shewing how the Atmoſphere refracts the rays of the ſun, moon and ſtars, which fall on it.

HAVING ſpoken a little on the nature and manner of refractions in general, we ſhall next come to conſider the refractifying power of the air. The terreſtrial atmoſphere refracts the rays of the ſun, moon and ſtars, which fall on it; and changes their directions by propagating the light in other lines, making the apparent places of the ſun and moon different from their true places, and brings the ſun in ſight every clear day before he riſes in the horizon, and to keep them in view for ſome minutes after they are really ſet below it. For at ſome times of the year the ſun and moon is ſeen ten minutes longer above the horizon than they would be if there were no refractions, and above ſix minutes every day at a mean rate.

The refractifying power of the air being ſuch, that it apparently elevates the ſun and moon, when at the horizon, 33 minutes of a degree, and 45 ſeconds more when taken at a mean computation. And what we are now particularly to take under conſideration, is to deſcribe how, and in what manner, the refraction of the air operates, and affects the ſun and moon differently, according to the length of their reſpective diſtance from the earth, and that very point in the atmoſphere in which they are ſeen, when they ſet in the ſenſible horizon.

CHAP. II.

For if the air bend and refract the rays of the moon 33 minutes when ſhe is on the horizon, it muſt needs certainly refract the rays of the ſun as much when he is on the horizon at the place of incidence; and if they are both refracted by the air more than half a degree, which according to the nature of things they muſt certainly be alike in, then there cannot be ſuch a very great difference between the diſtances of the ſun and moon from the earth, as ſome would have it to be. For when the moon ſets in the ſenſible horizon, ſhe is but a degree, or at leaſt 58 minutes from the rational horizon, and the ſun is eight or ten ſeconds from the rational horizon when he ſets in the ſenſible horizon. But if the ſun were 400 times more diſtant from the earth than the moon is, he would be ſeveral degrees paſt the rational horizon before he ſet in the ſenſible horizon, by means of this refraction, when it is duly conſidered; and this will be more evidently underſtood by the following figures.

Plate 1. Fig. 4.

Let the inmoſt circle of the 4 figure encompaſs the globe of the earth, and the outmoſt circle contain the whole ſphere of air; the line drawn through the centre of the earth produced, be the rational horizon; and the line drawn from the ſurface of the earth the ſenſible horizon; and the declining line between theſe two, be a ray of light running in a ſtraight line, and touching the atmoſphere at the point P, ſeen by a ſpectator upon the ſurface of the earth at A; let M be the moon, and the point S the ſun; and let them be underſtood to be in conjunction at the time of their ſetting, as at the time of an eclipſe, ſo as that the rays of both ſun and moon may run in one direct line, and touch the atmoſphere at one and the ſame point.

And as it is a moſt certain principle in philoſophy, that the rays of both ſun and moon are broken and bended, at that point of the air where they are ſeen to touch at their ſetting; ſo here in this figure the ſpectator at A, ſees the rays of both the ſun and moon refracted at the point of the air at P, and there turned out of a rectilinear courſe: but as the rays of both the ſun and moon run in a ſtraight line to one point in the atmoſphere, as at P, and from thence directed in another line to a ſpectator at A, this ſhews to us, that if the ſun were ten times more diſtant from the earth than the moon is, the ſun at S, would be on the rational horizon, when the moon at M, is ſome diſtance from it; or when the moon is at the rational horizon the ſun would be paſt it. CHAP. II.

The 5 figure here ſhews the moon to be on the horizon, when the ſun is paſt it; and both directing their rays in one ſtraight line, as at conjunction. In this figure, and the other above it that we laſt deſcribed, the earth is drawn many times too large for the ſun and moon's diſtance from it, their diſtance from the earth being many times more than this figure repreſents it to be; but they both ſhew the manner how the ſun and moon, when in conjunction, direct their rays in one ſtraight line to one point in the air, and how the air directs the ray to a ſpectator on the earth. Let then a ſpectator be at B, as marked on this figure, and ſee a ray from the ſun and moon, when in conjunction, directed in one ſtraight line to the point P, and at P the ray is bended and turned to B, the moon at M is one degree from the rational horizon; but the ſun would be many degrees paſt it, if he were 400 times more diſtant from the earth than the moon is, which the aſtronomer that is well Plate 1. Fig. 5.

CHAP. II. ſkilled in the mathematics and optics, will very eaſily come to know.

The young aſtronomer, who comes to calculate the difference betwixt the ſun and moon's diſtance from the earth, muſt know the true nature of refractions, and how they apparently elevate the luminaries of the heavens, when near the horizon differently, according to their reſpective diſtances from the earth; and be well grounded in the mathematics, ſo as that he can draw lines both in a proper length, both to the moon and ſun's orbit; and know how the rays of a luminous body are directed in a ſtraight line when in a pure medium, and how it is bended by the refractifying power of the air, and in what diviſion of the line the rectilinear ray is broke at the place of incidence.

Plate 1. Fig. 6. We ſhall next come to conſider the 6 figure in this figure. Let the two co-centric ſemicircles repreſent and circumſcribe the one half of the earth and atmoſphere, the ſtraight line D the earth's diameter produced to the ſun's orbit, the line S a ray of the ſun, the line M a ray of the moon, meeting the ſun's ray at the point P, the place of incidence in the atmoſphere, and both ſeen by a ſpectator at C on the earth; it is here manifeſt by theſe lines M and S, that if the moon were as near the rational horizon as the ſun, when they both ſet in the ſenſible horizon, that the ray of the moon would be much more bended and turned out of a ſtraight line than the ſun's ray is, which is contrary to the nature and laws of refraction. This is another demonſtration that the moon muſt be at one degree diſtant from the rational horizon, and the ſun ten ſeconds of a minute from it, when they ſet in the ſenſible horizon, although the ſun be not much above

ſix times more diſtant from the earth than the moon is; unleſs we ſhould ſuppoſe, that the atmoſphere has much more power over the moon in bending her rays, and turning them out of a ſtraight courſe, than it hath over the ſun, which cannot be the caſe; for the rays of the ſun are more luminous than the moon's rays are, and penetrate the atmoſphere as much as the moon's rays doth. CHAP. II.

As from the 6 and laſt figure we have ſhewed, that the ſun's rays are as much refracted by the atmoſphere, as the moon's rays are; we now come to deſcribe from this 7 figure, that the rays of the ſun are not refracted any where in ſpace, and ſo turned out of their rectilinear courſe, before they meet with the atmoſphere, at leaſt for any thing known in the ſcience of aſtronomy. Let then the two co-centric circles repreſent the one half of the earth and air about it, the ſtraight line H the earth's rational horizon produced to the ſun's orbit, the line S a ray of the ſun refracted or bended in ſpace near the orbit of the moon in its way to the atmoſphere at the time when the ſun is ſetting, the line M a ray of the moon directed to the point P, touching the air at the ſun's contact there at the time of ſetting, and ſeen at D by a ſpectator on the earth; theſe two lines M and S, ſhew, that the rays of the ſun and moon are both alike refracted until they be at the moon's orbit, but the ſun's ray is bended upwards, after that it has paſt the orbit of the moon. And ſo if this were certainly true, the ſun might be ten ſeconds of a minute above the rational horizon, when the moon is 58 minutes of a degree above it; altho' the ſun in that caſe, were ſeveral hundred times more diſtant from the earth than the moon is. But Plate 1. Fig. 7.

CHAP. II.

we have formerly demonſtrated, and will make ſtill further to appear, that the ſun and moon are both alike refracted by the atmoſphere, from the place of incidence at ſetting, and their rays directed in the ſame manner to a ſpectator on the earth. And as to that of the ſun's rays being any where in ſpace bended or refracted by a diaphanous ſubſtance, between the outmoſt verge of the atmoſphere and the ſun's orbit, is a circumſtance unknown in philoſophy.

And ſince we know of no refraction that the ſun's rays meet with, but the air, and that the ſun and moon are equally refracted in and by the air, we are to conſider them as viewed in a ſtraight line from the point of the atmoſphere in which they ſet, to that point where the horizon or earth's diameter produced, toucheth the ſun's orbit. And as this ſtraight line is ſuppoſed to go thro' the moon's centre, when ſhe is 58 minutes of a degree from the ſenſible horizon, this line, after paſſing the moon, will meet with the line of the horizon produced, much ſooner than ſome men have ſuppoſed it would. Which is afterwards to be demonſtrated a little further.

We come next to deſcribe the two different angles under which the earth's diſc is to be underſtood, as ſeen from the ſun and moon. When the centre of the ſun ſets on the ſenſible horizon, it is then ten ſeconds of a minute from the rational horizon, and being then 33 minutes of a degree and 45 ſeconds refracted by the atmoſphere; and when theſe two are added together, they make 33 minutes of a degree and 55 ſeconds. And when this is conſidered in its proper manner, the ſemi-diameter of the earth is ſeen under an angle of 33 minutes and 55

ſeconds from the orbit of the ſun at ſetting, as is repreſented by the 8 figure, where E is the earth and S the ſun; and when the centre of the moon ſets on the ſenſible horizon, it is then 57 minutes of a degree and 49 ſeconds from the rational horizon at a medium, and the moon being then 33 minutes of a degree and 45 ſeconds refracted by the atmoſphere; theſe two being added together, they make one degree 31 minutes and 34 ſeconds, ſo that the ſemi-diameter of the earth is ſeen under an angle of one degree 31 minutes and 34 ſeconds, from the orbit of the moon at ſetting, as is here repreſented by figure 9, where E is the earth, and M is the moon. But in both this and the 8 figure, the ſun and moon at S and M, are placed much too near the earth, according to the diameter of its diſc at E and E; and the angle of the earth's ſemi-diameter will be more properly underſtood in the following exhibitations. Plate 1. Fig. 8. Plate 1. Fig. 9.

So the angle under which the earth's diſc is ſeen from the moon or the ſun, is to be conſidered not only as it ariſes, or is produced by the moon's being one degree from the horizon at her ſetting, and the ſun's being but 10 ſeconds of a minute from it at his ſetting; but here proper allowance muſt be made for the refraction of the air, which is about 34 minutes of a degree. This refraction of the air, as ſaid is, has near about ſix times more effect upon the ſun in elevating him in his orbit at the horizon, than it hath upon the moon; becauſe the ſun is ſo many times more diſtant from the atmoſphere, and that point of it where the rays are broken and bended out of a ſtraight line, than the moon is.

To exhibit this, as in figure 10, Let E be a ſpectator on the earth, viewing the ſun and moon, when in Plate 1. Fig. 10.

CHAP. II.

conjunction, at their ſetting, and P the point of the atmoſphere in which they are both then ſeen, and the black point at G, a point in ſpace upon the line in which the moon and ſun's rays are directed in one ſtraight courſe; and let this point at G be equidiſtant from P, that the ſpectator at E is. And for example's ſake, we ſhall ſuppoſe that the points at E and G are each of them 600 miles diſtant from the point at P, which is the place of incidence; though it makes no difference whether it be exactly ſo much, or if it be more or leſs. Now it is evident by this figure, and the nature of the thing itſelf, that the points at E and G are equally bended or bowed down on their reſpective lines from the point at P; the line from E to P being near a ſtraight, and the line from P to G being exactly ſtraight. And if a ſtraight line were drawn between the points at E and G, it would in no place touch the bended or curve line at P, produced both ways, but at the two points E and G. And this ſtraight line would be at its greateſt diſtance from the curve or bended line, juſt under the point at P; ſo the point at G is 34 minutes of a degree refracted in its orbit. And if there were any ſuppoſitious luminous body moving in ſpace, equidiſtant from the atmoſphere that the point G is, it would be as much refracted in its orbit, and its rays as much bended by the air, as the moon's rays are in her orbit, or the ſun's rays in his orbit; becauſe all the three direct their rays in one ſtraight line to the point of the atmoſphere at P, where they are all bended alike.

And in like manner, Let another line be drawn from the point at E to the point at M, to the moon in her orbit; this would make another kind of angle from the former, by the line that was drawn to the

PLATE II.

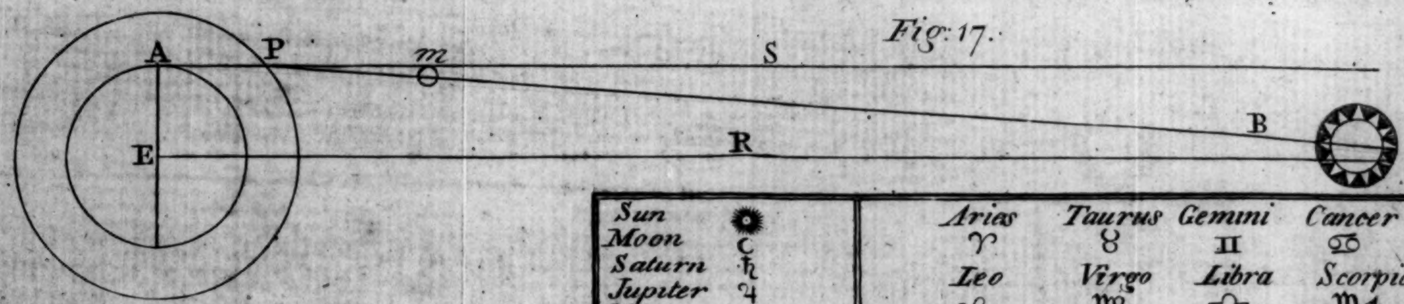


Fig: 17.

Sun	☉	Arias	Taurus	Gemini	Cancer
Moon	☾	♈	♉	♊	♋
Saturn	♄	Leo	Virgo	Libra	Scorpio
Jupiter	♃	♌	♍	♎	♏
Mars	♂	Sagitarus	Capricarnus	Aquarius	Pisces
Venus	♀	♐	♑	♒	♓
Mercury	☿				

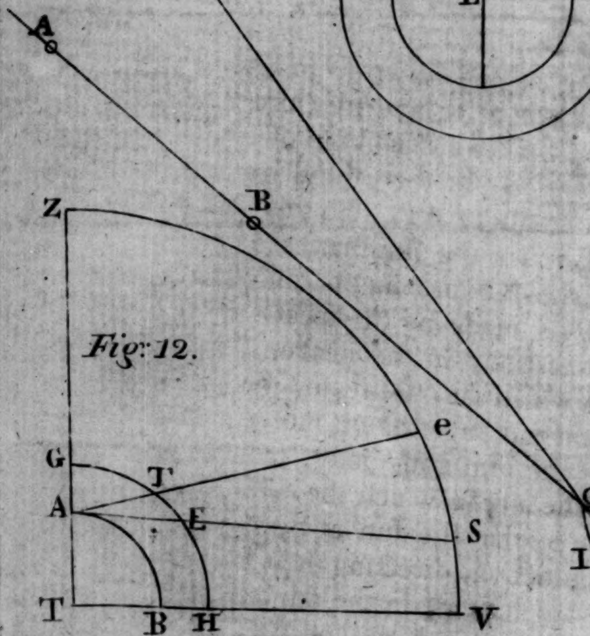


Fig: 12.

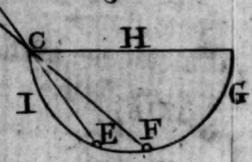


Fig: 16.

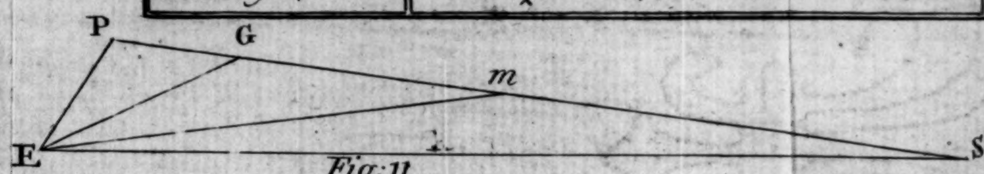


Fig: 11.

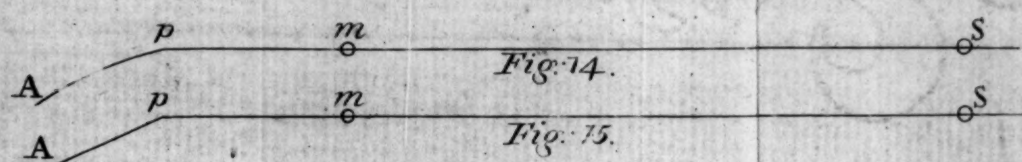


Fig: 14.

Fig: 15.

point at G. And alſo, Let a third line be drawn from the point at E to the point at S, that is to the ſun in his orbit; this would make another kind of angle from the former two; although the ſun at S, and the moon at M, and the point at G, be all three equally refracted, and their rays bended at the point P, in the atmoſphere alike. CHAP. II.

But becauſe theſe three lines laſt deſcribed, cannot be ſo well diſcerned on figure 10, the angles being ſo ſmall, we ſhall exhibit them here by the 11 figure. The ſtraight line drawn from E to G forms one kind of angle at E, and the other line drawn from E to M forms another kind of angle at E, and the third line drawn between E and S makes a third kind of angle at E; but yet S, M, and G, as they ſtand on one ſtraight line, have all one angle at P. So this ſhews that the atmoſphere refracts the luminaries of the heavens, particularly the ſun and moon, all alike. But yet the angle that is made by the ſpectator on the earth, the luminous body in the heavens, and the point of the air in which they are ſeen at ſetting, may be different. And this angle differs juſt according to the diſtance of the luminous body, from the place of incidence in the air, in which they are ſeen. So we ſee by figure 10, that the ſun at S, and the moon at M, as at conjunction, directing their rays in one ſtraight line to the point P, in the atmoſphere, and making different angles with the ſpectator at E upon the earth, ſo as that the moon at M is but about a degree from the rational horizon, and the ſun at S is at ten ſeconds from it; and yet the ſun may be but about ſix times more diſtant from the earth than the moon is. Plate 1. Fig. 11.

We ſhall now come to obſerve the ſame thing

CHAP. II.

from Dr. Keill's works, an eminent writer upon the Copernican ſyſtem. In his aſtronomical lectures, p. 241, and we ſhall give both the figure and the deſcription of it in the Doctor's own form and words. "For," ſays he, "the terreſtrial atmoſphere refracts "the ſun's rays, and the rays of all the ſtars which "fall on it, and changes their directions by propa-"gating the light in other lines, making the appa-"rent places of the ſtars different from their true "places. All the ſtars, by refraction, appear higher "or nearer our vertex than they would be, were "there no air; ſo that the light might arrive to us "without refraction.

Plate 1. Fig. 12.

"In figure 12, Let ZV be a quadrant of a vertical "circle in the heavens, deſcribed from the centre of "the earth T, under which is AB a quadrant of a "circle on the ſurface of the earth, and GH a qua-"drant on the ſurface of the atmoſphere: and let S "be any ſtar from which proceeds the beam of light "SE, falling on the ſurface of the air in E; now ſince "this ray comes from the ethereal air much rarer "than that which is nearer the earth, and grows ſtill "denſer the nearer it is to us, this ray of light as it "proceeds, will conſtantly be refracted and bended, "ſo that it will arrive at our eye in the curve line "EA: ſuppoſe the right line AT to touch the circle "in A, according to the direction AT the ray of "light will enter the eye at A; and becauſe all ob-"jects are ſeen in the line according to whoſe direc-"tion the rays enter the eye, and ſtrike upon the "ſenſorium, the object will appear in the line AT, "that is in the heavens as at E, which is nearer to "our vertex than the ſtar really is. And it may "even happen, that a ſtar which is below the hori-

" zon may be ſeen above it. This refraction is alſo CHAP. II.
" the cauſe why the two great luminaries the ſun and
" moon, when one of them is above the horizon,
" and the other below it, both may appear above
" the horizon; ſo that the moon has been obſer-
" ved eclipſed when ſhe was below the horizon, and
" the ſun above it." Thus far the Doctor.

So we ſee from this figure of Doctor Keill's, as well as from the former figures, that a ray from the ſun and moon, or from the ſtars, is bended at E upon the outmoſt ſurface of the atmoſphere, and at that point of the air turned out of a ſtraight line, even juſt where it enters the atmoſphere, as well as that reflecting and bending, which he ſuppoſes the ray wherein its paſſage through the air to the eye of the ſpectator on the earth, from the place where it firſt entered the air. "For," ſays the Doctor, "the moon has been
" obſerved eclipſed when ſhe was below the horizon,
" and the ſun above it. Therefore, her ray muſt have
" been refracted, or reflected, when it entered on the
" verge of the atmoſphere, and there in that place
" bended out of a ſtraight courſe."

For, we ſee by the figures 14 and 15 that it is the ſame thing whether the ray that comes from P to A is directed in a curve, or if it comes from P to A in a ſtraight line; becauſe the line MS is bended at the point P juſt in the ſame manner in the one caſe, as well as in the other.

CHAP. III.

CHAP. III.

Giving a ſhort deſcription of the 13 Figure which is too large to be bound in this book.

HAVING thus far inveſtigated how, and in what manner, the ſun and moon are refracted by the air, we now come to give an eſſay, or deſcription of the ſun and moon's diſtance from the earth, as by figure 13. Let E be one half of the earth and atmoſphere about it, and M a quadrant of the moon's orbit, and S a portion of the ſun's orbit; and becauſe it is ſhort we make it ſtraight, and the ſtraight line SH the ſenſible horizon, the other ſtraight line RH the rational horizon, and both produced to the ſun's orbit, and the inclining line between them a ray of light directed from the ſun and moon at ſetting, when they are in conjunction, as at the time of an eclipſe; though the caſe be the ſame at any other time. Yet we inſtance the time of conjunction, becauſe when the ſun and moon are in that ſituation, their rays are more ready to be underſtood to be directed in one and the ſame ſtraight line to the point of the atmoſphere in which they are ſeen to ſet. And let this ray be directed to the point of the air at P, and ſeen by a ſpectator at the ſurface of the earth at A.

And when this ray or line is traced forth in its courſe from the eye of the ſpectator at A to the point of the air at P, and from thence to the moon's orbit, and further to the ſun's orbit at S, the ray is ſeen by the ſpectator at A to keep on the ſenſible horizontal line to the point of the atmoſphere at P, and

after it is paſt P bends and inclines in a ſtraight line downwards through M at the moon's orbit, to S at the ſun's orbit, when it juſt very near touches the rational horizontal line there: now on this ſtraight line, the moon at M is ſeen to be about one half of a degree below the ſenſible horizon, and above a whole degree from the rational horizon: but the ſun at S is within a few ſeconds of the rational horizontal line, and yet they are both alike refracted, and direct their rays at the ſame time and to the ſame point of the atmoſphere in a ſtraight line.

In this diagram the moon's orbit is about 37 ſemidiameters of the earth diſtant from it, and the ſun is about ſix times more diſtant from the earth than the moon is: but this 13 figure is ſix foot long, and cannot be herein bound.

From this deſcription, it is evident that the ſun cannot be at ſuch an immenſe diſtance from the earth as it is reckoned by ſome men to be, and ſuch a great diſproportion between the ſun and moon's diſtance from the earth as is ſaid by ſome who have embraced the Copernican ſyſtem of aſtronomy. But it is moſt agreeable to the doctrine of Moſes; for he ſays in the book of Geneſis, that "the Lord made two "great lights, the greater light to rule the day, and the "leſſer light to rule the night: he made the ſtars alſo." Now ſince the moon is one of the two great lights in the firmament of heaven, ſhe is greater than one of the ſtars; and as bodies appear in a ſubduplicate proportion according to their diſtance, the planet ſtars appear to be leſſer bodies than the moon, and they muſt be within ſuch a diſtance to the earth, as that they really are leſſer bodies than the moon is: and this is agreeable to the common ſenſe of all man-

CHAP. III. kind. For when the ſun and moon are viewed in the firmament, the ſun in his place there, appears rather to be about ſix times more diſtant from the earth than the moon is, than four hundred times, as is given out in the Copernican ſcheme of aſtronomy, when their meaſures are calculated in their outmoſt extent.

As this 13 figure is of ſuch a ſmall compaſs and only drawn upon paper, it cannot delineate the ſun's diſtance exactly, but muſt be at leaſt a fifth part from it according to this ſcheme. But if make a quadrant of 45 foot radius, upon a level plain, and divide its limb into degrees, and as much of it as is neceſſary, by minutes and ſeconds, and at its centre draw a ſemicircle or quadrant of a circle for the ſurface of the earth, and near about it another ſemicircle or quadrant of a circle for the ſurface of the atmoſphere: let the earth's ſemicircle be ſix inches of radius, and from the earth's centre draw a ſtraight line to the limb of the quadrant for the rational horizon; and from the earth's ſurface, or rather from the ſurface of the air, draw the other ſtraight line to the limb of the quadrant for the ſenſible horizon; and between theſe two draw an inclining line from the point of the atmoſphere, as at ſun and moon's ſetting, alſo to the limb of the quadrant; and let this inclining line, from the point of the air at ſun and moon's ſetting, terminate on the limb of the quadrant at 10 or 12 ſeconds above the line of rational horizon at the ſun's orbit; this inclining line, as ſaid is, will exhibit a ray of light from the ſun and moon, when in conjunction, at their ſetting, from their place in the firmament. And as the inclining poſition of this ſtraight ray is cauſed by refraction, the places of the

ſun and moon upon it, and their proper diſtances from the earth, may very near be exhibited by it, when proper allowance is made for the earth's parallax.

And what we have now ſaid on this ſcheme, is further inveſtigated by that well known experiment in the ſcience of optics. For example, as in figure 16, Let GHI be an empty baſon, and place this baſon where the ſun ſhines obliquely upon it, and obſerve where the ſhadow of the rim C falls on the bottom as at F, then fill it with water, and the ſhadow will fall at E; which proves that the rays of light falling on the ſurface of the water are refracted or bent downwards into it. Plate 2. Fig. 16.

This experiment, by a baſon of water, is brought by the writers on optics to ſhew, that when a ray of light paſſes out of one medium into another, it is refracted, or turned out of its firſt courſe. And this is more or leſs, as it falls more or leſs obliquely on the refracting ſurface which divides the two mediums. And it is likewiſe alſo brought by aſtronomers to exemplify and prove the refractifying power of the earth's atmoſphere in ſome reſpects. But what we bring it for here, is further to inveſtigate that when a ray of light paſſes out of one medium into another, either out of a denſer medium into that which is more pure and thin, or out of a pure and thin medium into that which is more denſe, the ray runs in a ſtraight courſe until it meets with the refracting ſurface which divides the two mediums, if the medium itſelf be all equally denſe, or equally pure and thin. For as in this 16 figure, if place the baſon where the ſun ſhines obliquely upon it as from A, and obſerve where the ſhadow of the rim C falls on the bottom as at F, then fill it with water and the ſhadow will Plate. 2. Fig. 16.

CHAP. III. fall at E, then again as before, place the bason at night under the moon when she is at the same elevation in the firmament that the sun was at, then suppose the moon to be at B and you will observe the shadow of the rim of the empty bason to fall at F, and filled with water it will fall at E, just in the same manner as when it was placed under the sun at A in the former case. And the same will also be the case if place a candle or torch at A or B, the shadow of the rim C, whether the candle be at A or B, will fall at F into the empty bason, and at E when it is filled with water, in the same manner when the candle is placed in the one situation, as well as when it is placed in the other.

Plate 2. Fig. 17. So we see by the rules of catoptrics, as in the 17 figure, that when the sun is just setting on the sensible horizon, he is much nearer the rational horizon than the moon is, by means of this refracting power of the air, although at that time they were exactly in conjunction. For in this figure 17, Let E be the earth, and A the circumambient air encompassing it about S the sensible horizon, R the rational horizon, and B the sun, and M the moon, and P the place of contact where a ray from the sun and moon meets with the atmosphere on the sensible horizon at A. So these last two figures exemplify and explain one another as to the effect which the refraction of the air hath upon the sun and moon, according to their different distances from the earth, so as to keep the sun, in appearance, longer above the sensible horizon when he is realy below it, than the moon is, at the time of their setting: which sheweth that the sun is much lower in his orbit than the moon is, when they are both setting in the sensible horizon.

CHAP. IV.

CHAP. IV.

Shewing how that the Parallax, and the Refraction differently affect the ſun and moon in their apparent elevation or depreſſion.

WE ſhall next ſhew from figures 18 and 19, how that the parallax and the refraction differently affect the ſun and moon in their apparent elevation or depreſſion. For in figure 18, Let E be the earth, M the moon in her orbit, and S the ſun in his orbit, and ABDZ the zodiac; now, as in this figure, a ſpectator at E on the ſurface of the earth ſeeth the ſun and moon both at D in the zodiac in the line ED, which is their apparent place; but a ſpectator at C, as ſuppoſed from the centre of the earth, would ſee the moon in the zodiac at A in the ſtraight line CA, which is her true place; ſo that the moon's parallatic angle would be AD in the zodiac; and a ſpectator at C, would ſee the ſun at B, ſo that the ſun's parallatic angle would be BD, which is a leſs angle than that which the moon is ſeen under, as the angle BD is leſs than the angle AD. So we ſee that the moon's true place, as ſeen from the centre of the earth, is A, and her apparent place, as ſeen from the earth's ſurface, is D, and the ſun's true place is B, but his apparent place is D; ſo that the parallax depreſſeth both of them, but it affecteth the moon much more than the ſun, as they are obſerved in the zodiac among the ſtars. Plate 3. Fig. 18, 19.

We will alſo ſee from figure 19, how that the refraction elevateth the ſun and moon differently in a Plate 3. Fig. 19.

CHAP. IV.

different manner; for in this figure, the ſpectator at A on the earth ſees the moon at B in her orbit, in the the ſtraight line APB which is her apparent place: but at the ſame time, by means of refraction, the moon's true place is M, and ſo ſhe is realy ſeen in the curve line APM, ſo that the angle which is cauſed by refraction is BM on the moon's orbit, and thereby ſhe is ſo much elevated as B is higher than M; and a ſpectator at A ſees the ſun at D in his orbit in the ſtraight line APBD, which is his apparent place, yet at that time, by virtue of the refraction, the ſun's true place is S, and ſo he is ſeen in the curve line SMPA, ſo that the angle which is made by refraction is DS on the ſun's orbit, and thereby he is ſo much elevated as D is higher than S.

But this elevation that is made by refraction, has much more effect upon the ſun in his orbit than upon the moon in her orbit; for the refracted angle upon the ſun's orbit is the arch SD, which is as much as the ſemidiameter of the earth; but the refracted angle on the moon's orbit is the arch MB, which is but a ſixth part of the ſemidiameter of the earth, and therefore refraction elevates the ſun in his orbit ſo ſo much more than the moon in her orbit: and this in proportion according to the refracting power of the atmoſphere. For if the ſun and moon were ſtill more refracted when the moon was at N, the ſun would be at O in his orbit; and ſo conſequently the ſun would be a conſiderable ſpace paſt the rational horizon, before the moon came upon it at their apparent ſetting in the evening on the ſenſible horizon.

Plate 3. Fig. 19.

And this demonſtrates to us how that the ſun is longer ſeen above the horizon than the moon is, when their comparative diſtance from the earth is

Fig. 19

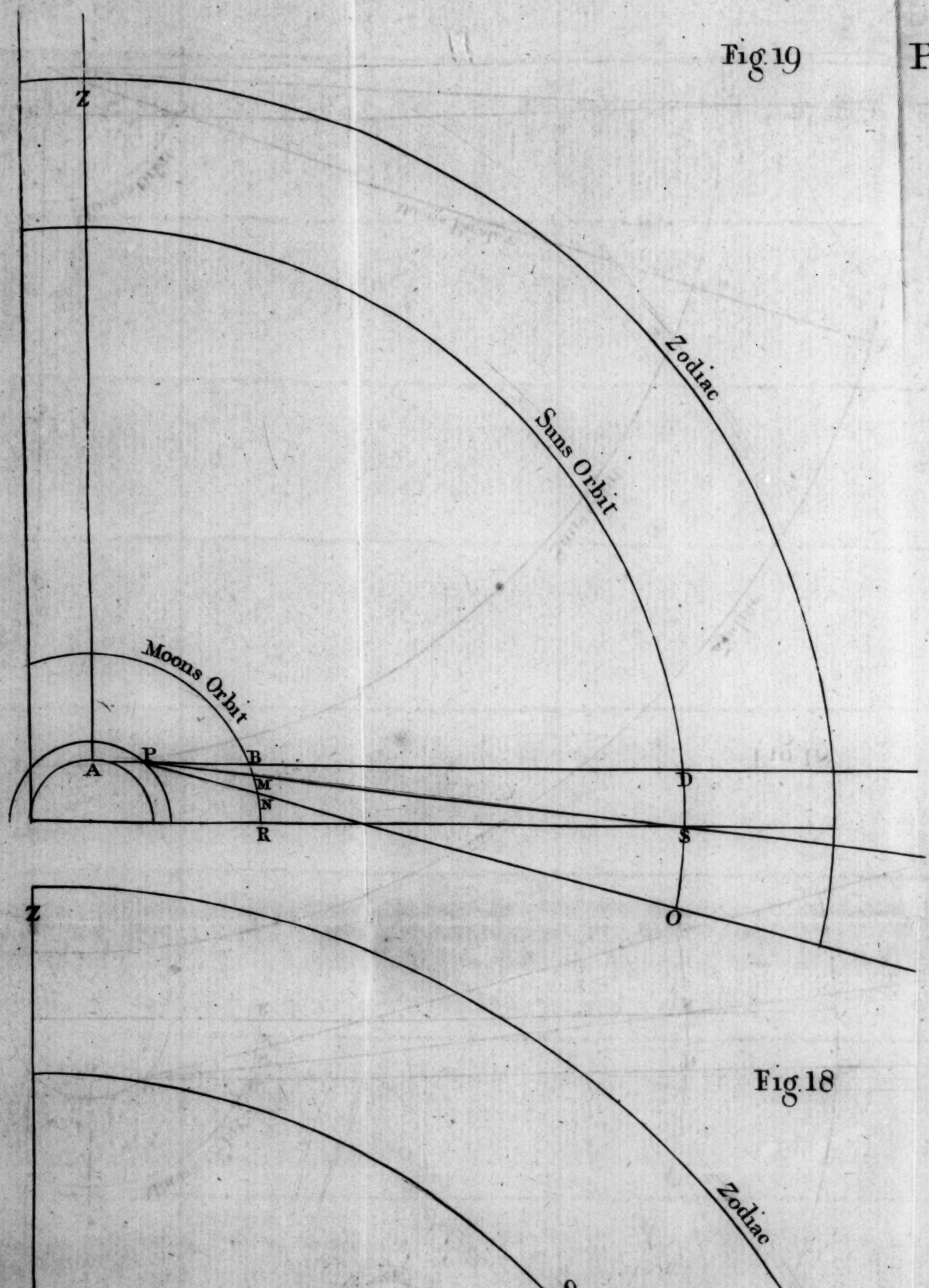
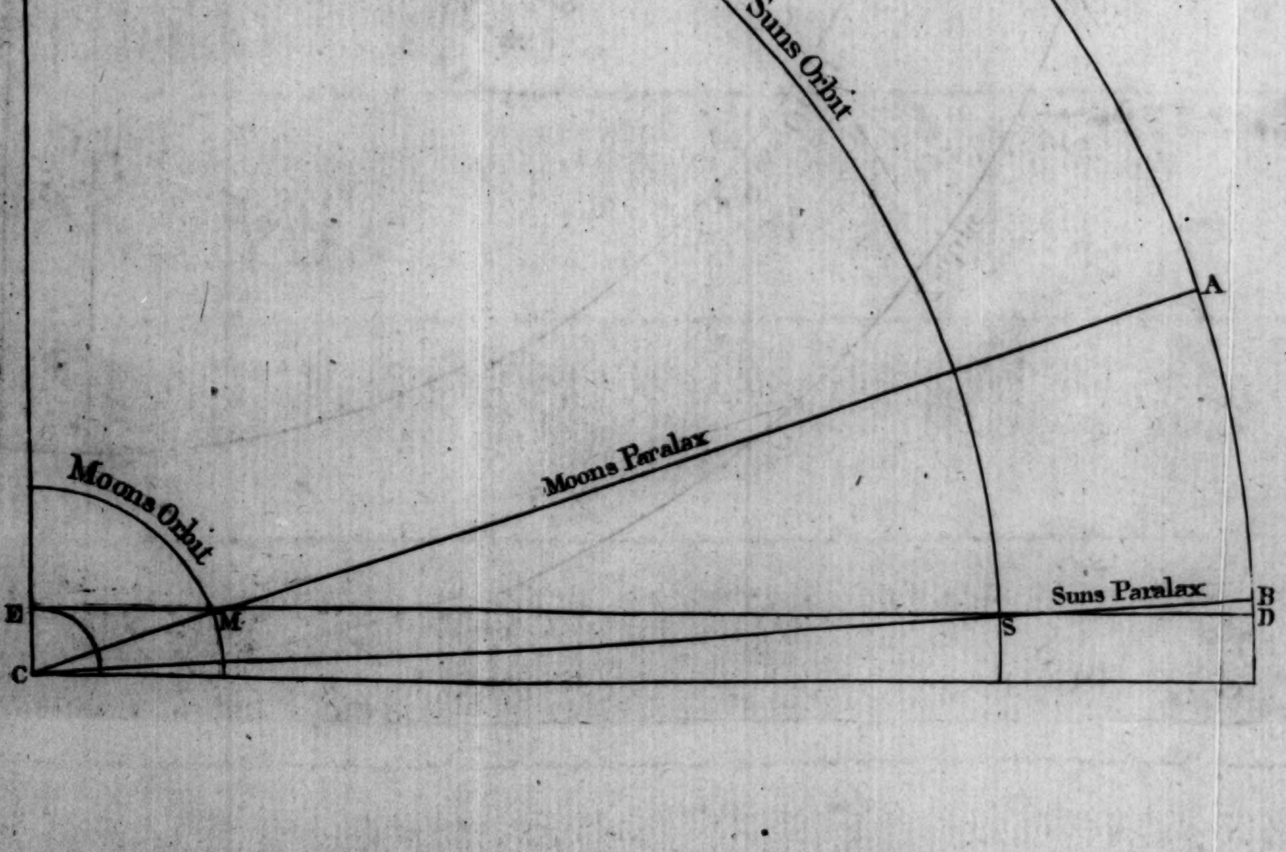

Z
Zodiac
Suns Orbit
Moons Orbit
A
P
B
M
N
R
D
S
O

Fig. 18


Z
Zodiac
Suns Orbit
Moons Orbit
Moons Paralax
Suns Paralax
A
E
M
C
S
B
D

taken near about the proportion which we have formerly given. CHAP. IV.

But although this method which we have taken in ſhewing the comparative diſtance of the ſun and moon, by means of refraction, ſheweth that the ſun cannot be very many times more diſtant from the earth than the moon is, yet this proportional diſtance of theſe two luminaries muſt be taken from the degree by which the moon is refracted when on the horizon: and as we come to know the exact quantity of the moon's refraction, in her orbit, ſo we ſhall certainly come to know the ſun's proportional diſtance from the earth in his orbit.

But after what we have above ſaid, concerning the nature of a parallax and refraction, the young aſtronomer whoſe ideas are poſſeſt with the Copernican ſcheme of aſtronomy, and who is only inſtructed in the knowledge of the mathematical figures by which that ſcheme is demonſtrated, ſhould ſtill heſitate in his mind, about the nature of a parallax and refraction, ſo as to think that the one juſt balances the other, and as the one elevates the ſun or moon, ſo the other depreſſeth them in the horizon, which ſome who are not acquainted with this our ſcheme of aſtronomy, have very ſtrenuouſly diſputed for; we ſhall thenceforth ſhew, what is properly to be underſtood of a parallax in the inveſtigation of the ſun's diſtance from the earth. We do not in this mean to underſtand the different views that we have of the ſun and moon in the zodiac amongſt the ſtars, as ſuppoſed to be ſeen from the centre or ſurface of the earth, ſuch as in figure 18, when the moon is viewed from the ſurface of the earth at E, ſhe is ſeen in the zodiac at D; but as viewed from the centre of the earth at C, Plate 3. Fig. 18.

CHAP. IV.

ſhe is ſeen in the zodiac at A; and when the ſun is viewed from the ſurface of the earth at E, he is ſeen in the zodiac at D; but as ſeen from the earth's centre, his place is at B. All theſe different views of the ſun and moon, from the earth's ſurface or it's centre, are all foreign to our purpoſes in taking the ſun's diſtance from the earth, being not ſo immediately connected with it. But in the inveſtigating of the ſun and moon's diſtance from the earth proportionally, we have only to conſider the different kind of angles which the ſemidiameter of the earth makes on the ſun and moon's orbits to a ſpectator on the ſurface of the earth at A, as in figure 19; or what proportion the ſemidiameter of the earth bears on a quadrant of the moon's orbit, and the difference of this proportion to what the earth's ſemidiameter bears on a quadrant of the ſun's orbit. For we ſee, as in this figure, that the diſtance between B and R is of a greater proportional extent on a quadrant of the moon's orbit, than the diſtance between D and S is on a quadrant of the ſun's orbit. And what we have particularly to remark on this, concerning a refracted ray from the ſun and moon in the horizon, is, that the refracting ray hath a greater effect upon the ſun than on the moon, at the time of their ſetting; for it elevates the ſun, ſo that he is ſeen by a ſpectator at A on the earth, as in this figure, when he is at or near the rational horizon at S; but when the moon is viewed from the ſame point at A the refraction elevates her but about a ſixth part of the earth's ſemidiameter on her orbit below the ſenſible horizon, as at M. And although the earth, in this figure, be drawn too large for the orbits of the ſun and moon about it, yet it ſhews the manner of refraction.

Plate 3. Fig. 19.

PLATE IV.

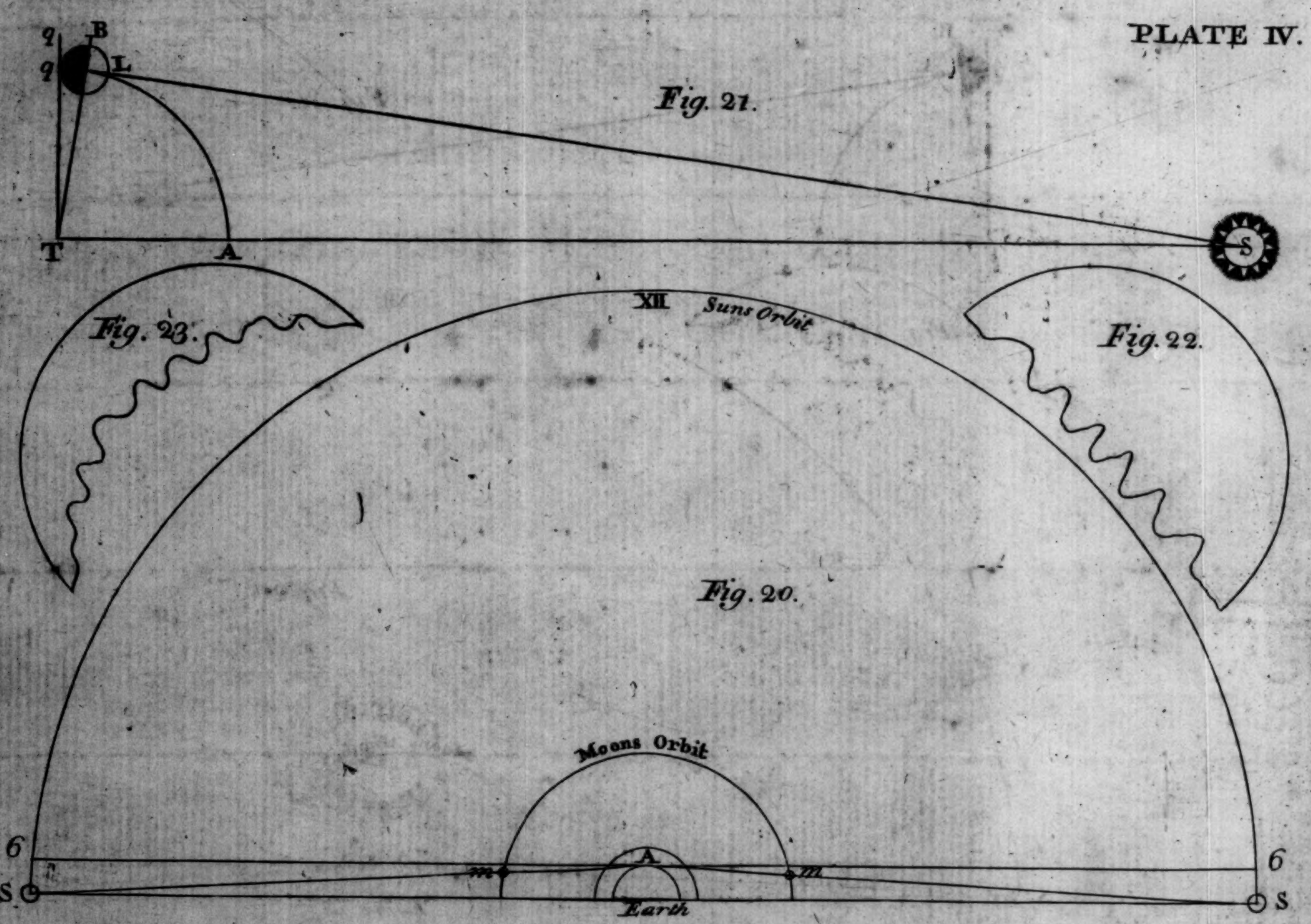


Fig. 21.
q
q
q
B
L
T
A
S
Fig. 23.
XII
Suns Orbit
Fig. 22.
Fig. 20.
Moons Orbit
6
6
S
S
m
m
A
Earth

CHAP. V.

CHAP. V.

Shewing that if the ſun were 400 times more diſtant from the earth than the moon is, he would be ſeen above the ſenſible horizon near 13 hours when at the equinoctial.

NOW as the moon revolves about the earth, from the meridian to the meridian again, in 24 hours and 48 minutes, ſhe will go a fourth part round in a fourth part of that time, viz. in 6 hours 12 minutes; ſo that when the moon is in the equinoctial, ſhe will go from our meridian to the rational horizon in 6 hours 12 minutes; and at that time ſhe is more than a degree below the ſenſible horizon. And the ſun circulates around the earth in 24 hours, ſo he will go a fourth part round in the ſpace of 6 hours; and when he is in the equinoctial, he goes from our meridian to the rational horizon in 6 hours time: and when he is there, the ſun at a medium, is only about 8 or 10 ſeconds from the ſenſible horizon.

Let figure 20 repreſent the orbits of the ſun and moon around the earth, the moon in the inmoſt circle, and the ſun in the outmoſt circle. This figure ſheweth how that the ſun, when he is in the equinoctial, is ſeen by a ſpectator at A, on the ſurface of the earth, to ariſe in the morning at 6 o'clock, he being then but a few ſeconds of a minute from the rational horizon. And in the ſame manner the ſpectator in the evening ſees the ſun ſet at 6 o'clock in the rational horizon, by means of refraction, when the ſun's diſtance is taken about ſix times above the moon's

Plate 4. Fig. 20.

CHAP. V. from the earth. But the ſun's diſtance, according to this method, can only be properly conſtructed and calculated according to the greatneſs or ſmallneſs of the curve, which the ſun and moon's refracted ray makes on the point of the atmoſphere, where it is broken and bended down to the ſpectator on the ſurface of the earth, viewing it there; and even a very ſmall degree of refraction would make the ſun to be ſeen in the ſenſible horizon at 5 o'clock in the morning, and at 7 o'clock in the evening, when he is in the equator, if he were 300 or 400 times more diſtant from the earth than the moon is.

And if the ſun were 400 times more diſtant from the earth than the moon is, and the 34 minutes of refraction calculated upon him, as the Copernican ſcheme doth, the ſun would be ſeen near 13 hours above the horizon when on the equator, and the moon only 12 hours 24 minutes, becauſe the ſun's refracted ray would make him be ſeen near half an hour above the horizon when he was really below it.

Having explained ſome conſiderations that are particularly to be taken notice of, in finding how many times the ſun is more diſtant from the earth than the moon is, by means of refraction; we ſhall now ſhew ſome other methods, and which have been uſed by aſtronomers for this purpoſe.

CHAP. VI.

Of Hipparchus' and Ariſtarchus's method for finding the ſun's diſtance from the earth.

THERE was a method invented by Hipparchus, and has been made uſe of by Ptolemy and his

followers, and ſome other aſtronomers. It depends upon an obſervation of an eclipſe of the moon, and the principles on which it is founded, are; Firſt, in a lunar eclipſe, the horizontal parallax of the ſun is equal to the difference between the apparent ſemidiameter of the ſun, and half the angle of the conical ſhadow; Secondly, half the angle of the cone, is equal to the difference of the horizontal parallax of the moon, and the apparent ſemidiameter of the ſhadow, ſeen from the earth at the diſtance of the moon: it is therefore evident, that the half angle of the cone, is equal to the difference of the horizontal parallax of the moon, and the apparent ſemidiameter of the ſhadow ſeen from the earth. Wherefore, if to the apparent ſemidiameter of the ſun there be added the apparent ſemidiameter of the ſhadow, and from the ſum you take away the horizontal parallax of the moon, there will remain the horizontal parallax of the ſun; which therefore, if theſe were accurately known, would be likewiſe known accurately. But none of them can be ſo exactly and nicely obtained, as to be ſufficient for demonſtrating the parallax of the ſun; for very ſmall errors which cannot be eaſily avoided in meaſuring theſe angles, will produce very great errors in the parallax, and therefore will be a prodigious difference in the diſtance of the ſun, when drawn from theſe parallaxes. Wherefore, ſince from ſo ſmall miſtakes as this method is liable unto, the parallax and diſtance of the ſun vary ſo much, it is plain that the diſtance of the ſun cannot be obtained by this method.

Of Ariſtarchus's method for finding the ſun's diſtance.

Since the angle that the earth's ſemidiameter ſubtends at the ſun is ſo ſmall that it cannot be

CHAP. VI.

determined by any obſervation, Ariſtarchus Samius, an ancient philoſopher and aſtronomer, contrived a very ingenious way for finding the angle which the ſemidiameter of the moon's orbit ſubtends when ſeen from the ſun; this angle is many times bigger than the former, ſubtended only by the earth's ſemidiameter. To find this angle, he lays down the following principles.

That if a plane paſſed through the moon's centre, to which the line joining the ſun and moon's centre was perpendicular, this plane would divide the illuminated hemiſphere of the moon from the dark one; and therefore, if this plane ſhould paſs through the eye of a ſpectator on the earth, the moon would appear biſected, or like a half circle; and a right line drawn from the earth to the centre of the moon, would be in the plane of illumination, and conſequently, would be perpendicular to the right line which joins the centres of the ſun and moon. To exhibit this as figure 21, Let S be the ſun, and T the earth, ALQ a quadrant of the moon's orbit; and let the line SL, drawn from the ſun, touch the orbit of the moon in L, the angle TLS will be a right angle; and therefore, when the moon is ſeen in L, it will appear biſected, or juſt half a circle. At the ſame time, take the angle LTS the elongation of the moon from the ſun, and there we ſhall have the angle LST its compliment to a right angle; but we have the ſide TL, by which we can find the ſide ST, the diſtance of the ſun from the earth, and ſo in the finding of the moon's diſtance from the quadrature, where ſhe is biſected, we would come to know the ſun's diſtance from the earth. But the difficult point is to determine the moment of time exactly

Plate 4. Fig. 21.

Plate 4. Fig. 22. & 23.

when the moon is bifected, or in its true dichotomy; for the moon's furface is not only rough and uneven, but there are upon it high mountains, and deep vallies, which cover the whole face of the moon. For when the moon is viewed with a telefcope, we find that there is no regular line which feparates light and darknefs in the moon's furface; but the confines of thefe parts, appear as if it were toothed and cut with innumerable notches and breaks, and it is not only fo at the moon's dichotomy or bifection, but it appears alfo in any other phafes of the moon, bigger or lefs than a dichotomy. No right line feparates light and fhade, for the mountainous or light parts of the moon, feem to run out amongft the vallies or dark parts upon her furface.

But although the moon's furface be fo uneven, yet her edge appears not toothed and notched as the curve bounding the light and dark places; for the moon's body being of a globular or fpherical figure, what we call the edge of the moon's difc is not a fingle line fet round with mountains, in which cafe it would appear irregularly indented, but a large zone, having many mountains lying behind one another, from the obferver's eyes. We fhall find that the mountains in fome rows will be oppofite to the vallies in others, and fo fill up the inequalities as to make her appear quite round, for which the edge of the moon's difc appears more bright and luminous, than her fide near her centre doth; for the fun fhines bright upon the edge of the moon's difc, to the outmoft point of each of her horns.

Plate 4. Fig. 22. & 23.

We fay then, that there is fome difficulty in drawing the line of dichotomy upon the moon's fide. For firft, fome will have it drawn all along the moon's

CHAP. VI.

ſide, from the one edge to the other, where ſhe is wholly bright and illuminated, and this they take to be the true dichotomy. Secondly, whereas in taking the true biſection of the moon's body, it muſt be when the outmoſt prominent illuminated bright points near the moon's centre are in a ſtraight line with her upper and lower horns; for the moon may be ſaid to be truly biſected when the outmoſt points of her horns, and the outmoſt parts or points of the illuminated parts near the centre appear in a ſtraight line. In the firſt of theſe caſes, the moon comes not to be biſected apparently, until ſhe be within half a degree of the quadrature; but in the ſecond caſe, the moon is realy biſected ſome degrees before the quadrature.

For there is an obſcure faint brightneſs between the very outmoſt prominent points that are illuminated on the moon's ſide, and the line where ſhe is wholly bright and illuminated, that is ready to deceive the unwary beholder, in taking the real dichotomy of the moon with the micrometer. For the moon's illuminated edge, even to the outmoſt points of her horns, is always moſt bright and clear; but the moon's ſide that is towards the earth, near the centre in the dichotomy, is more dark and obſcure. For theſe illuminated mountains or parts, that are ſeen on the moon's ſide, appear more ſperſe and diſunite, and of a duſky colour, the nearer that they are to the centre of her diſc, which makes her appear deficient of a half circle, even when ſhe is in the true dichotomy.

CHAP. VII.

CHAP. VII.

THE following five chapters, with the plates belonging to them, perhaps may be difficult at firſt to be underſtood, by ſome of the readers that are not acquaint with the method of calculating the ſun's diſtance from the earth, by the tranſit of Venus over the ſun's diſc, in the years 1761 and 1769. But the reader who is acquainted with the methods uſed by aſtronomers in calculating the diſtance of the ſun, by the tranſits of Venus, will very readily ſee, by the explication of the following plates, that thoſe who have endeavoured to find the diſtance of the ſun and Venus from the earth, by their deſcriptions given, they have ſhown that they have erred greatly, in not conſidering and taking in the quantity of the refraction, that the ſun and Venus were under, at the time and place of the obſervations.

Of Dr. Halley's method for finding the parallax and diſtance of the ſun from the earth, by the tranſit of Venus over the ſun.

THE method which was invented by Dr. Edmund Halley and others, for finding the parallax and diſtance of the ſun from the earth, by an obſervation of the body of Venus ſeen paſſing over the ſun's body, in June the 6th 1761. And as the requiſites neceſſary for making this obſervation, were both ingenious and intricate, we ſhall give them in

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the Doctor's own words, that the reader may the better understand the obſervations which we ſhall make upon them, and how the whole of the apparatus, and different proſpects of this tranſit of Venus, is adapted for ſhewing that the ſun's orbit is not very many times more diſtant from the earth, than the moon is.

Dr. Edmund Halley's diſſertation on the method of finding the ſun's parallax and diſtance from the earth, by the tranſit of Venus over the ſun's diſc, June 6th 1761, tranſlated from the Latin in Motte's abridgment of the Philoſophical Tranſactions, vol. 1. p. 243. with additional notes.

The diſſertation on the method of finding the ſun's parallax and diſtance from the earth, by the tranſit of Venus over the ſun 1761, and the improvement which was made by aſtronomers upon the Doctor's method, together with the obſervations that were taken of this tranſit, which were collected from the obſerver's accounts, printed in the Philoſophical Tranſactions for the years 1762 and 1763, which ſhews much of the vivacity and ingenuity of the aſtronomers, both in Britain and in other places abroad, which were concerned about the obſervation of this phenomena.

But as the whole of what is there ſaid, concerning this tranſit of Venus, ſhews, that both Dr. Halley, and all the other aſtronomers who wrote upon the order and manner of the tranſit, were of opinion, that the earth is carried with a motion about the ſun, from weſt to eaſt. And alſo, Mr. Short, in deducing the quantity of the ſun's parallax from the beſt of thoſe obſervations which were made both in Britain and abroad, found it to have been eight and a half ſeconds of a minute, on the day of the tranſit. And

which according to the obſerver's method in projecting thereof, it would ſuppoſe the ſun to be near about 400 times more diſtant from the earth than the moon is. Now as to both theſe, viz. of the immoveableneſs of the earth, and the diſtance of the ſun from the earth, we are now to take under our conſideration, even from this tranſit of Venus itſelf, both from Dr. Halley's and others theory and method of projecting of it, and from the obſervations which were made of it on the day of the tranſit.

CHAP. VIII.

Of an obſervation of the tranſit of Venus at Port-Nilſon.

DR. Halley propoſed that an obſervation of this tranſit ſhould be taken in thoſe places where Venus would be in the middle of the ſun's diſc at midnight, that is, in a part of Hudſon's Bay near a place called Port-Nilſon, where Venus would enter upon the ſun a little before its ſetting, and go off a little after its riſing; and likewiſe alſo another obſervation to be taken in places under the oppoſite meridian to the former, where Venus would be neareſt the ſun's centre, when the ſun would be vertical, viz. on the northern ſhores of the Bay of Bengal, or rather in the kindom of Pegu, where the ſun, when Venus entered his diſc, would be almoſt four hours toward the eaſt, and as many to the weſt when ſhe left him. And by the Doctor's calculation, the duration of this tranſit at Port-Nilſon, would be near 17 minutes of time longer, than on the northern ſhores of the bay of Bengal. And although, by the Doc-

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tor's calculation, the planet of Venus was to have paſſed only 4 minutes of a degree below the ſun's centre, yet ſhe realy did paſs almoſt 10 minutes of a degree below it. This we ſay, will make no difference as to the following demonſtration, ſhewing that the earth is immoveable.

In figure 25, Let the outmoſt circle repreſent the orbit of the ſun, and the next circle to that, the orbit of Venus, and the inmoſt two circles be the earth and atmoſphere about it. The parallel lines towards the left-hand ſide of the figure, ſhew the ſenſible and rational horizon of Port-Nilſon in the evening; and the other two parallel lines, towards the right-hand, the ſenſible and rational horizon in the morning; and the inclining line, down to the rational horizon at the left hand, be the refracted ray of the ſun and Venus at the time of their ſetting; and the other inclining line at the right hand, the refracted ray at the time of their riſing. Now a ſpectator at Port-Nilſon, at the point P, would ſee the ſun at A and Venus at V, ſeveral minutes after they were realy below the ſenſible horizon in the evening, upon account of the refraction, and alſo the ingreſs of Venus upon the ſun's diſc. So likewiſe in the morning, the ſpectator at P, would ſee the ſun at B and Venus at U, ſeveral minutes before they were realy on the ſenſible horizon; and alſo, the egreſs of Venus from the ſun's diſc, by means of the horizontal refraction, which lengthens the time of obſervation of this tranſit at Port-Nilſon, or at a place to the north thereof, called New North-Wales.

Plate 5. Fig. 25.

Pl: 5

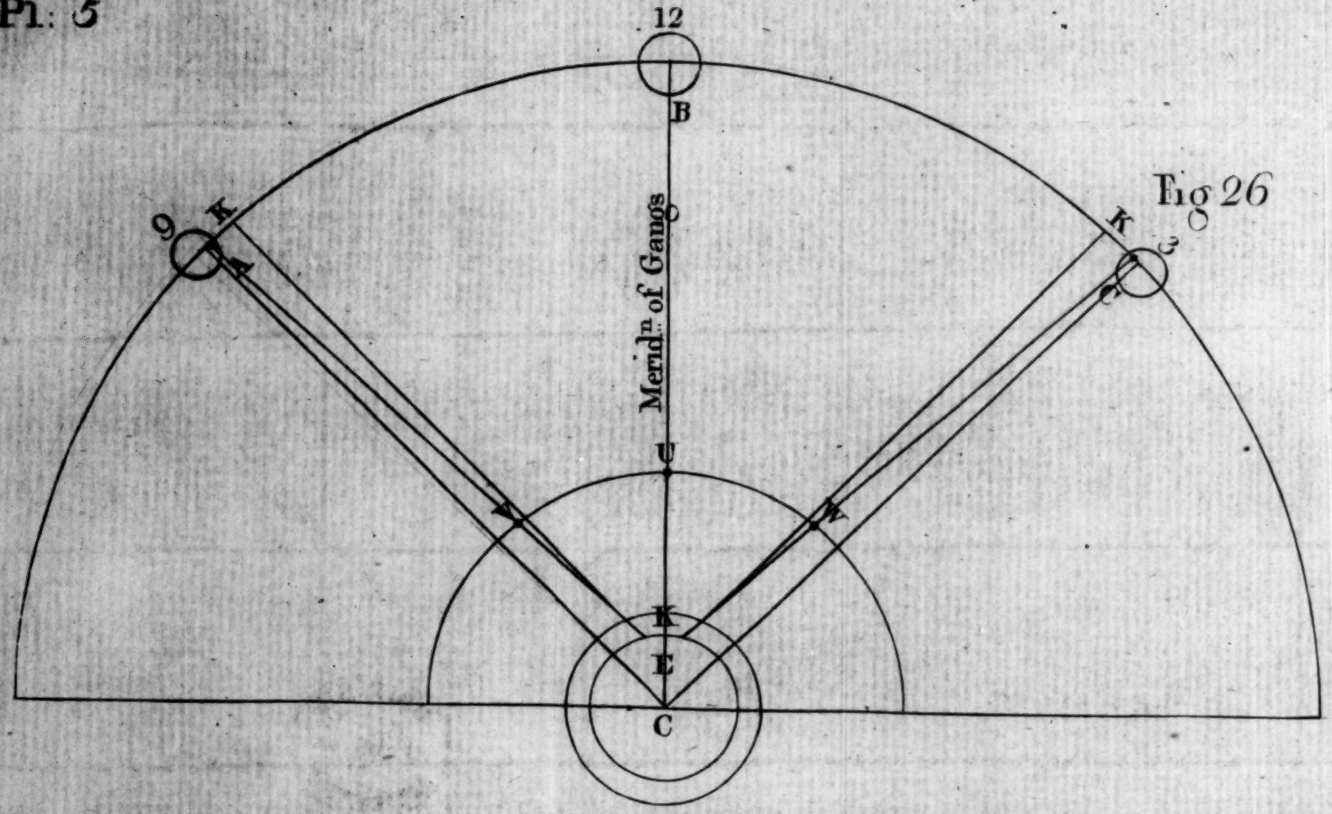

Fig 26

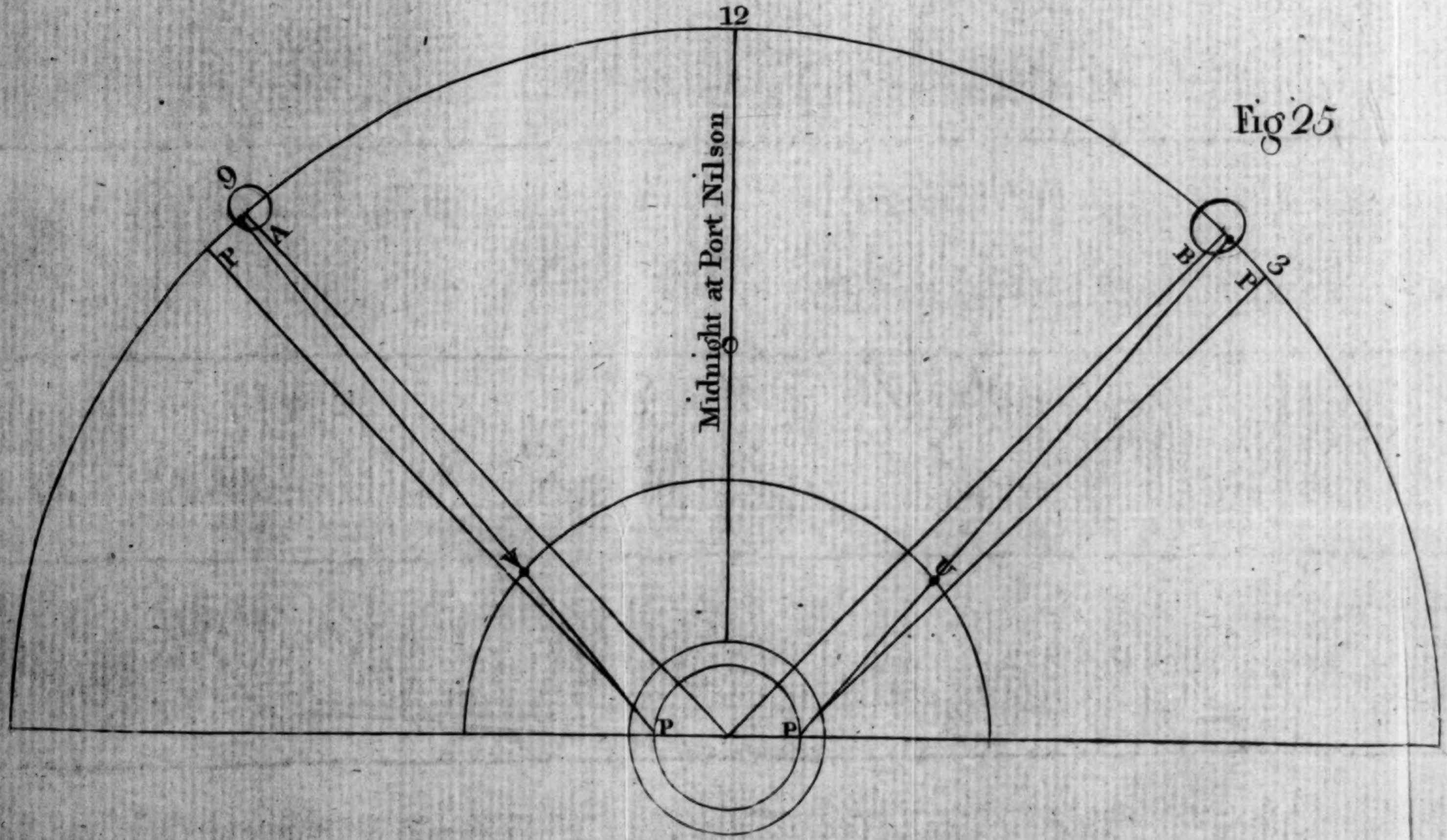

Fig 25

CHAP. IX.

Of an observation of the transit of Venus, at the Bay of Bengal.

AND for describing an observation taken in the opposite meridian to the former, where the sun was vertical at the middle of the transit, viz. at the northern shore of the Bay of Bengal. As from figure 26, Let the out-most circle represent the orbit of the sun, the next to that the orbit of Venus, and the two inmost circles the earth and circumambient air about it; the two parallel lines, towards the left-hand side of the figure, shew the quantity of the refraction, or how much the sun and Venus were there seen out of their true place, at the time of the ingress of Venus on the sun's disc; and the other two parallel lines towards the right hand, represent the quantity of the refraction, at the time of her egress, off the sun's disc; and the two inclining lines between the parallels on the left and right hand sides of the figure, shew the refracted ray of the sun and Venus, at the time of the beginning and end of the transit. Therefore, a spectator on the north coast of the Bay of Bengal, at the point E, would see the sun at A, and Venus at V, at the beginning of their conjunction at 9 o'clock, under the angle of a small refracted elevating ray. And when 12 o'clock at that place, the spectator at E, would see the sun at B and Venus at U, in the middle of the transit, near 10 minutes of a degree in the perpendicular, below the sun's centre. And at 3 o'clock in the afternoon, the

Plate 5. Fig. 26.

CHAP. IX.

ſpectator at E, would ſee the ſun at C and Venus at W, at the end of their conjunction, under the ſame angle of a ſmall refracted ray as the former, when they were at 9 o'clock forenoon.

Now as the ſun is much more refracted and elevated by the atmoſphere when in the horizon, than when he is 45 degrees above it; therefore, the ſun would be ſooner ſeen, in conjunction with Venus on the horizon, in the evening at Port-Nilſon, and longer ſeen before the conjunctive exit, at the horizon in the morning, than he would be at the coaſt of Bengal, where the ſun and Venus were 45 degrees above the horizon at the beginning of the tranſit, and as many degrees above the horizon, when the tranſit ended. The horizontal refraction elevates the ſun about 34 minutes of a degree, and at the altitude of 45 degrees above the horizon, he is only elevated above his true place 54 ſeconds of a minute; as is ſaid in the tables of refraction.

The atmoſphere refracts the ſun's rays ſo as to bring him in ſight every clear day, before he riſes in the horizon, and to keep him in view for ſome minutes after he is realy ſet below it. For at ſome times of the year, we ſee the ſun ten minutes longer above the horizon than he would be if there were no refractions, and above ſix minutes every day at a mean rate, as has been ſaid. And add as a demonſtration to this, as in figure 25, that the refracted ray of the ſun and Venus, made them to be ſeen in the ſtraight line from P to P, which hindered them to appear, as fallen backwards upon the radius line, drawn from the earth to the ſun's true place in his orbit, in the evening at Port-Nilſon, and forwards upon this radius line, produced the reverſe way from the earth, to

Plate 5. Fig. 25.

the ſun's true place in the morning. And compare with this, as in figure 26, that the refracted ray of the ſun and Venus, rendered them to be ſeen in the ſtraight line from K to K, which made them to appear as if they were ſo much more forwards than the radius line drawn from the earth's centre at C, to the ſun's true place in his orbit. When the ſun and Venus came firſt into conjunction, as obſerved at the coaſt of the Bay of Bengal, at 9 o'clock in the morning, and backwards from the radius line drawn from the earth's centre at C, to the ſun's true place at 3 o'clock in the afternoon, when the planet went off the ſun's diſc. So this accounts for the reaſon why that the duration of this tranſit was longer as ſeen at Port-Nilſon, or New North-Wales, than as ſeen from the north coaſt of the Bay of Bengal, although the earth be immoveable on its centre.

Plate 5. Fig. 26.

And although that we are deprived of the advantage that otherwiſe would have ariſen from obſervations made at Port-Nilſon, becauſe the tranſit was quite over before the ſun aroſe to that place in the morning, it ending ſomewhat ſooner than as given by the tables, to which Dr. Halley was obliged to truſt; and our aſtronomers did not think proper to make obſervations farther to the north of Port-Nilſon, where this tranſit of Venus was to be ſeen both in the evening and morning. And although the Doctor's ſcheme, in ſuppoſing the ſun to be immoveable, was a miſtake, yet his theory was juſt, in eſteeming, that if this tranſit was obſerved to the north of Port-Nilſon, its duration would be longer as ſeen from that place, than as ſeen from the Eaſt-Indies. And the above copper-plates, ſhew the ſame, by reaſon of refraction.

CHAP. IX.

After having ſpoke of the immoveableneſs of the earth, and ſhewed that it is ſo, even from or according to Dr. Halley's diſſertation upon this tranſit of Venus, we come next here to ſhew the ſun and Venus's relative diſtance from the earth, in reſpect of the moon's diſtance from it. When all the requiſites neceſſary for underſtanding the manner of this tranſit are taken together, in order to the making of a proper deduction from theſe, of the earth's parallatic angle as ſeen from the ſun.

Therefore the duration of this tranſit muſt be conſidered as obſerved in different latitudes, under the meridian where the ſun was vertical at the time when Venus was neareſt the ſun's centre. In the regions that the ſun, when Venus entered his diſc, was almoſt three hours towards the eaſt, and as many to the weſt when ſhe left him. And likewiſe, in different latitudes, under the oppoſite meridian to the former, in places where Venus was in the middle of the ſun's diſc at midnight, as in the laſt two plates. So likewiſe alſo, the duration of the tranſit is to be underſtood as obſerved under ſeveral different longitudes, between theſe two oppoſite meridians. And when all the obſervations that were taken of this tranſit are conſidered, particular regard is to be had to the quantity of the refraction that the ſun was under at that preciſe time of the obſervation, and how much the ſun was elevated above the horizon of the place of obſervation, both at the time of Venus's ingreſs upon the ſun's diſc, and egreſs from it.

From hence, then theſe three things are to be conſidered, Firſt, that to thoſe places where the tranſit began before 12 at noon, and ended after it, Venus had an eaſtern parallax from the ſun at the begin-

ning, and a weſtern parallax from the Sun at the end, which contracted and ſhortened the duration of the tranſit, by cauſing it to begin latter, and end ſooner at theſe places, than it did as ſeen from the Earth's centre, or under the meridian where Venus was in the middle of the Sun's diſc at midnight. Secondly, as the line of Venus's tranſit was in the ſouthern hemiſphere of the Sun's diſc, it is evident, that a northern parallax in her latitude, did cauſe her to deſcribe a longer line on the Sun, than if ſhe had no ſuch parallax; and a ſouthern parallax in latitude, did cauſe her to deſcribe a ſhorter line on the Sun, than if ſhe had no ſuch parallax, and the longer this line was, the ſooner was her total ingreſs, and the latter was the beginning of her egreſs; and juſt the contrary where the line was ſhorter.

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But Thirdly, when the Sun was in or near the horizon of any place of obſervation, at the time of Venus's ingreſs upon his diſc, there was there a greater quantity of refraction than in higher altitudes; which occaſioned the Sun and Venus to be elevated above their true place. So that in every horizontal obſervation of this tranſit, the beginning of the contact was ſeveral minutes ſooner ſeen, than from the Earth's centre. And as the duration of this tranſit was near ſix hours, there was a much ſmaller quantity of refraction at the end of the contact than at the beginning thereof, the Sun being then ſeen not ſo much above his true place. To all thoſe places that obſerved this tranſit in the morning, the refraction was greater, and about 9 o'clock in the forenoon when it ended it was leſs; and in theſe places where the Sun was vertical at the middle of the tranſit, the refraction of the air elevated the Sun, but a ſmall quantity towards

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the perpendicular, above his true place, both in the forenoon and afternoon, which occaſioned the duration of this tranſit of Venus to be ſhorter, as ſeen under this meridian, than to thoſe which obſerved the beginning thereof in the morning; or as ſuppoſed to be ſeen from the Earth's centre. And this even though the Sun be not above ſix times more diſtant from the Earth than the Moon is.

CHAP. X.

Sheweth the order of the refracted rays of the Sun, Venus and the Moon.

HAVING premiſed theſe things (which after due conſideration had) that are in themſelves plain and obvious, we come now to give the following demonſtrations. In our hypotheſis upon the Sun's diſtance from the Earth, we exhibited, as from figure 10, &c. that the angle, under which the Earth's diſc is ſeen from the Moon or the Sun, is to be conſidered not only as it ariſes, or is produced by the Moon's being one degree from the horizon at ſetting, and the Sun's being 8 or 10 ſeconds of a minute from it at his ſetting; but there muſt be alſo a proper allowance made for the refraction of the atmoſphere, which is about 34 minutes of a degree at the horizon, even at the Moon's orbit. This refraction of the atmoſphere has, we ſhall ſuppoſe, about ſix times more effect upon the Sun than it hath upon the Moon; becauſe the Sun is ſo many times more diſtant from the air, and that point of it, where the ray is broken and

Fig 28

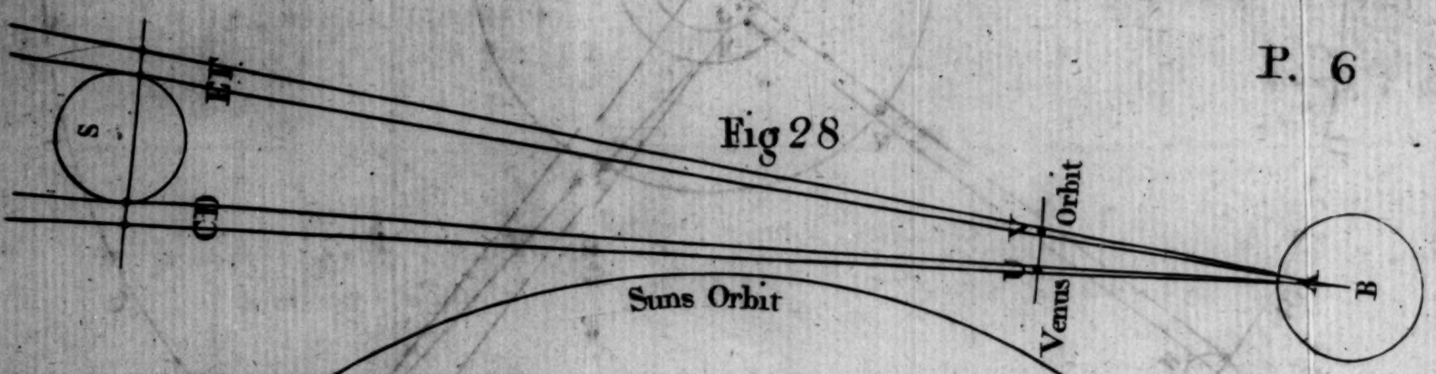


Fig 27

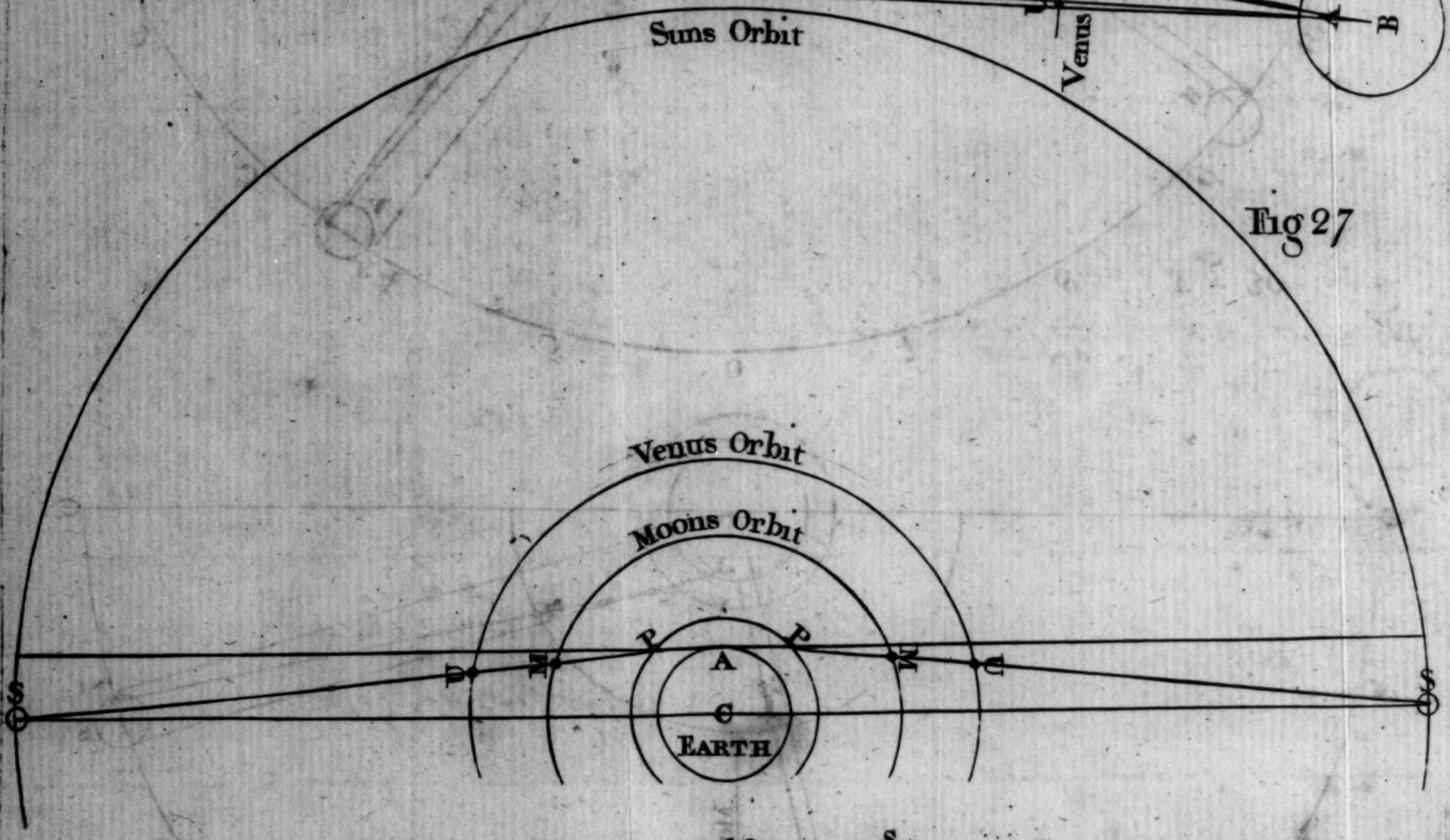


Fig 29

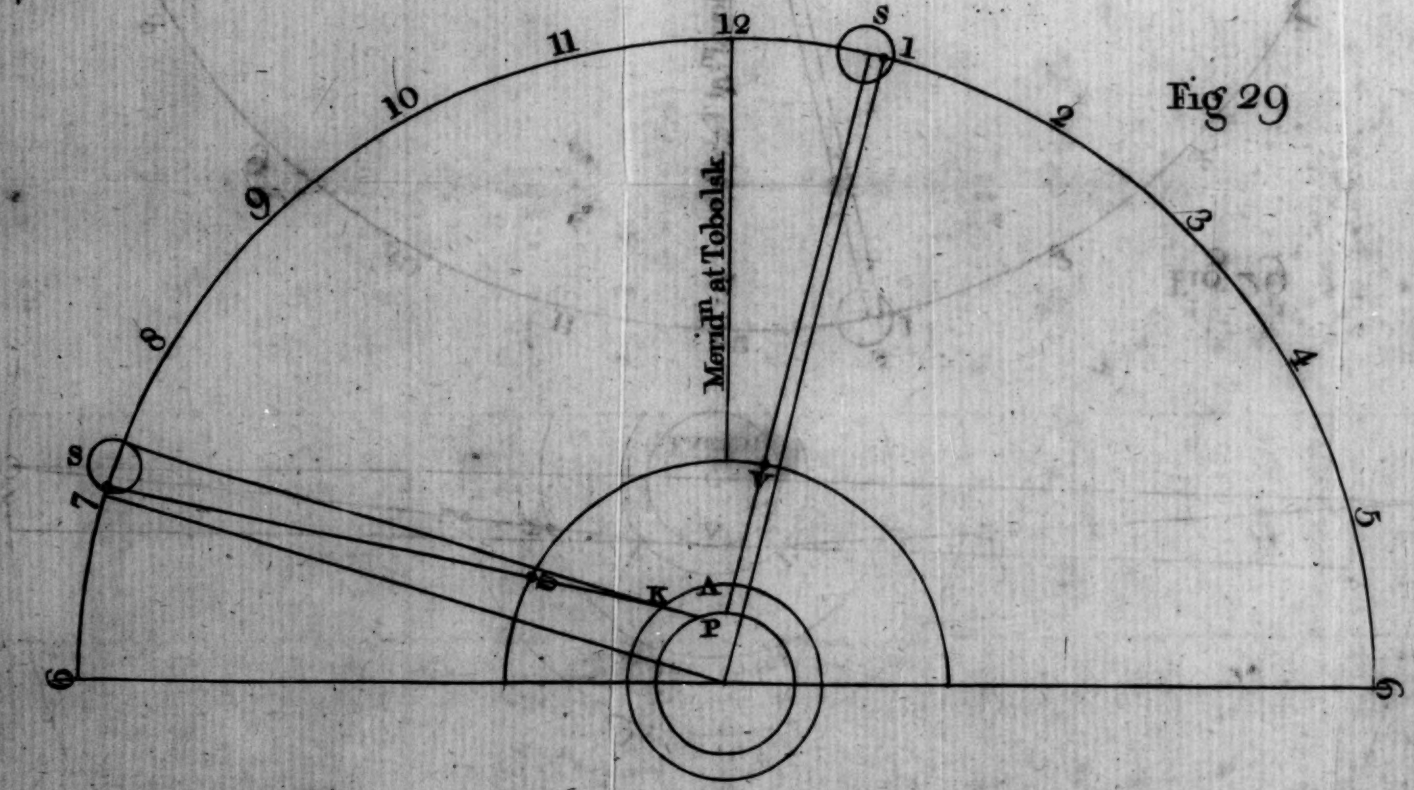
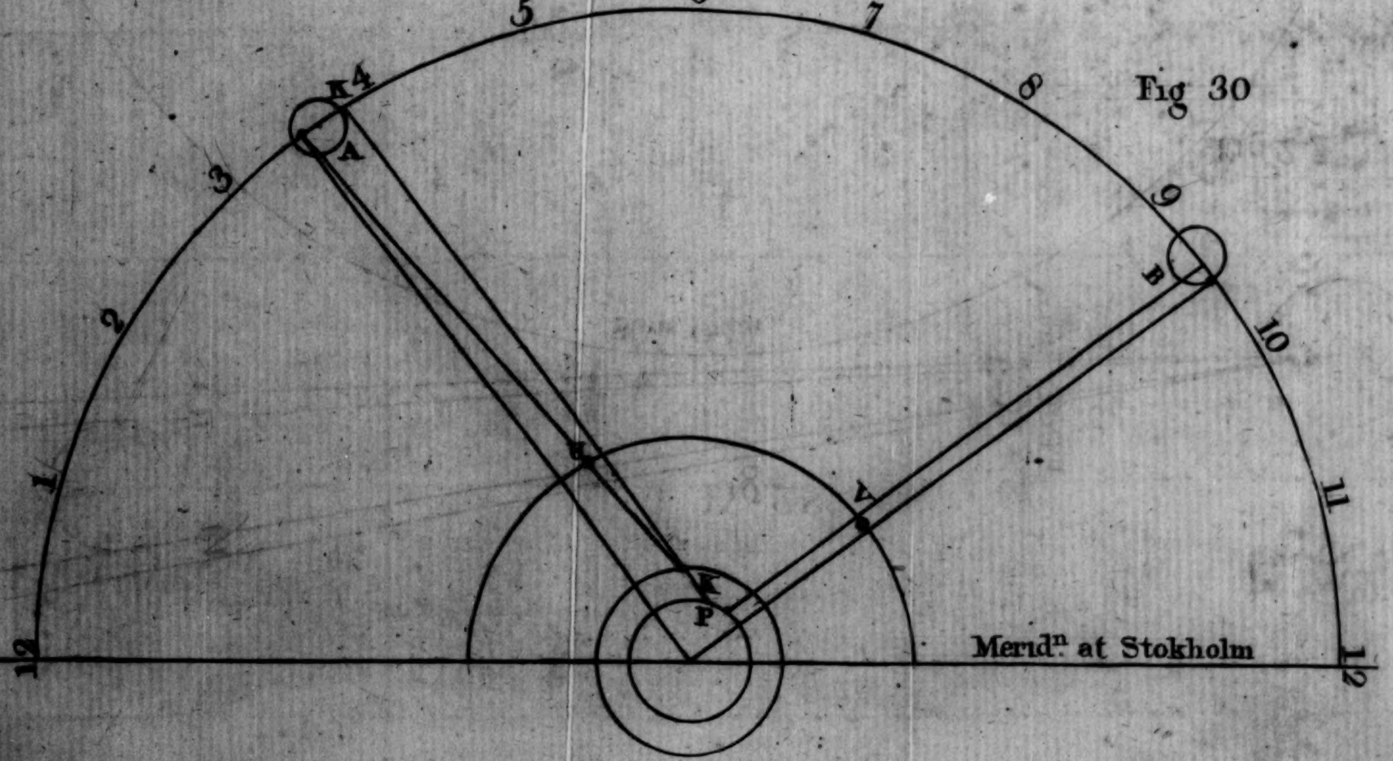


Fig 30



bended out of a ſtraight line, than the Moon is. CHAP. X.
Now take the Sun to be ſix times more diſtant from the Earth than the Moon is, and four times more diſtant than Venus is, when in conjunction; Venus has therefore a proportional quantity of refraction, in reſpect of her proportional diſtance from the Earth; ſo that if the Sun, Venus and the Moon, were all three in conjunction in the horizon, their refracted ray that is directed from them, would run in one ſtraight line to the ſame point in the atmoſphere, and there bended out of a rectilineal courſe, to a ſpectator on the ſurface of the Earth

To exhibit this, as in figure 27, Let the outmoſt circle repreſent the orbit of the Sun, the next to that the orbit of Venus, the third circle the orbit of the Moon, and the two inmoſt circles repreſent the Earth and atmoſphere about it, and the parallel lines produced both ways the ſenſible and rational horizon, and the two inclining lines from the horizontal atmoſphere, produced to the Sun's orbit, ſheweth the refracted ray of the Sun, Venus and the Moon, as in conjunction, when riſing in the morning, or ſetting in the evening. Now for perſpicuity in underſtanding of the figure, we have ſuppoſed the Sun, Venus and the Moon, to be all three in conjunction, or very near it, as ſeen from the Earth; and when they are in this poſition in the horizon, as ſaid is, a ſpectator at A, on the Earth's ſurface, ſees the Moon at M, and Venus at U, and the Sun at S, either at their riſing in the morning, or in their ſetting at night, at the points P and P in the horizon. The ray from the Sun at S, runs through or about Venus at U, and the Moon at M, to the point P, and is there broken out of its rectilinear courſe, and bended down to the eye

Plate 6. Fig. 27.

CHAP. X.

of the ſpectator at A, by reaſon of the refracting power of the air. So that when the Moon is refracted and elevated 34 minutes of a degree, above her true place in her orbit, when in the Horizon, the refracted ray from the point of the atmoſphere at P in the ſenſible horizon, runs down through the Moon's place in her orbit, in a ſtraight line to Venus's place in her orbit, and to the Sun's place in his orbit, in the rational horizon, and there obliquely interſects it, 'gainſt it be produced ſix times further diſtant from the Earth than the Moon is. So that the Sun muſt be but about ſo many times more diſtant from the Earth, than the Moon is from it.

And in like manner, as Venus is near four times nearer to the Earth, when in her inferior conjunction, than the Sun is, ſo in conformity, as her diſtance from the Earth is proportioned between the Sun and Moon's orbit, in like manner is her horizontal refraction conform to theirs. And alſo, in all their different elevations between the horizon and the meridian, As is the Sun and Moon more or leſs refracted in their orbits, ſo is Venus proportionally refracted in her orbit.

CHAP. XI.

Of the parallax of Venus, without any regard to refraction.

HAVING laid down this hypotheſis concerning the manner of refraction, we come to ſhew the parallax of Venus, without any regard to refraction,

We have before obſerved, that to thoſe places where the tranſit began three hours before 12 o'clock at noon, and ended as much after it, Venus had an eaſtern parallax from the Sun at the beginning, and a weſtern parallax from the Sun at the end; which contracted and ſhortened the duration of the tranſit, by cauſing it to begin latter, and end ſooner at theſe places, than it did as ſeen at the Earth's centre. This is cauſed, by reaſon that Venus is much nearer to the Earth than the Sun is, when in her inferior conjunction; for at that time ſhe is near four times nearer to the Earth than the Sun is to it; which we ſhall explain in the following manner, as the Earth is underſtood to be immoveable, and the Sun and Venus in motion. CHAP. XI.

In figure 28, Let A be the Earth, V Venus, and S the Sun; at the beginning of Venus's ingreſs on the Sun's diſc, to an obſerver placed at the Earth's centre at B, Venus at U appeared at D, juſt touching within the Sun's eaſtern limb. But at the ſame time, to an obſerver on the Earth's ſurface at A, Venus was at C in open ſpace behind the Sun, and to be obſerved in the line CUA. And at the time of Venus's egreſs off the Sun, to an obſerver at the Earth's centre B, Venus at V appeared at E, on the Sun's weſtern limb. But at that time, to a ſpectator at A, Venus was to be ſeen at F in the open ſpace before the ſun, and therefore to be obſerved in the line FVA; ſo that the duration of the tranſit was contracted, as obſerved from the Earth's ſurface; and the duration thereof leſs than its true duration at the Earth's centre, where it was 5 hours and 58 minutes, as given by the aſtronomical tables. But the duration between the two internal contacts, did not exceed 5 hours and 50 minutes, in ſome latitudes where the Sun was vertical at the middle of the tranſit. Plate 6. Fig. 28.

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And as that part of Venus's orbit, in which ſhe did move during her tranſit on the Sun, may be conſidered as a ſtraight line; and therefore a plane may be conceived to paſs both through it and the Earth's centre, to every place on the Earth's ſurface, cut by this plane. Venus was ſeen on the Sun, in the ſame path that ſhe would deſcribe as ſeen from the Earth's centre; and therefore in this plane, ſhe had no parallax of latitude either north or ſouth, but had a greater or leſs parallax longitude, as ſhe was more or leſs diſtant from the meridian, at any time during her tranſit. And if the air had no refraction in elevating a luminous body, to be ſeen above its true place, the Sun's parallax might have been determined pretty exactly, by calculating the difference between the time of the duration of this tranſit, as obſerved where the ſun was vertical at the middle of the conjunction, in a place cut by this plane on the Earth's ſurface, and the time of the duration thereof as ſeen from the Earth's centre. But tho' the refraction of the air be but ſmall in itſelf, yet the refracted ray makes a very conſiderable angle, 'gainſt it be produced to the Sun's orbit in mathematical conſtruction; therefore the difference between the duration of this tranſit, as ſeen where the Sun was vertical at the middle of the conjunction, and the time of the duration thereof as obſerved from the Earth's centre, is not a juſt ground for conſtructing the Sun's parallax, and calculating his diſtance from the Earth, without at the ſame time taking in the quantity of the refraction, that the Sun was under at the time of obſervation.

CHAP. XII.

CHAP. XII.

Of the observation of the transit of Venus at Tobolsk in Siberia, and at Stockholm Observatory.

THE Reverend Dr. Bliss, Mr. Short, Messrs. Ellecot and Dollan'd, &c. observed this transit in England; Mr. Margenten at Stockholm, Mr. Hellant in Lapland, Mr. Gister at Hernasand, Mr. de la Lande at Paris, Mr. Chape at Tobolsk in Siberia, the Rev. Mr. Hirst at Madrass, Professor Mathenci at Bologna, Mr. William Magee at Calcutta, and Mr. Mason observed it at the Cape of Good Hope. All these gentlemen appear to have used great diligence and fidelity in their observations; though there was some very small difference amongst them, which may be easily accounted for, from the difference of the agility and quickness of peoples' eyes, and the different magnifying powers of those telescopes, through which the ingress and egress were seen.

In this dissertation, we need not make particular remarks on all the different observations that were taken of this transit of Venus; for they appear all of them to have been made with much carefulness and accuracy in the observers. It is sufficient to our present purpose, to take two of them that were made at a proper distance in degrees of longitude, and very near under the same degree of latitude. The two observations that were taken, the one at Stockholm, and the other at Tobolsk in Siberia, may suffice to our purpose. Stockholm and Tobolsk are both very near under the 59 degree of north latitude;

CHAP. XII.

but the one is at 20 degrees, and the other at 80 degrees of east longitude, which was a proper distance for making useful observations; these two places being about 60 degrees of longitude distant from one another.

At Tobolsk, in Siberia, Mr. Chape observed the total ingress to be at 7 hours 0 minutes 28 seconds in the morning, and the beginning of egress to be at 49 minutes 20½ seconds after 12 at noon; so that the whole duration of the transit, between the internal contacts, was 5 hours 48 minutes 52½ seconds, as seen at that place.

And at Stockholm Observatory, the total ingress was observed by Mr. Margenten to be at 3 hours 39 minutes 23 seconds in the morning, and the beginning of egress at 9 hours 30 minutes 8 seconds; so that the whole duration, between the two internal contacts, as seen at that place, was 5 hours 50 minutes 45 seconds, which was 1 minute 52½ seconds more than as seen at Tobolsk in Siberia. And as Stockholm is about 60 degrees of longitude distant from Tobolsk, the difference of the duration of this transit, as seen from these two places, when compared together; and the time of the whole duration of the transit, as seen from both these places, when compared with the duration thereof as seen from the Earth's centre, would help us to understand that the Earth's semidiameter, as seen from the Sun, or which is the same thing, the Sun's horizontal parallax, to be between 8 and 10 seconds, if there were no refraction. But the difference of the quantity of refraction that the Sun was under, at the time of the observation of this transit at Stockholm and Tobolsk, is to be considered in the following manner.

For deſcribing the obſervation that was taken at Tobolſk. In figure 29, Let the outmoſt circle be the Sun's orbit, the next circle ſhews the courſe of Venus at the time of her inferior conjunction, and the two inmoſt circles encompaſſes the Earth and Atmoſphere about it, the two parallel lines towards the left-hand ſide of the figure, ſhew the quantity of the Refraction that the Sun and Venus were under, at the time of the Ingreſs of Venus on the Sun's diſc. The inclining line between theſe two parallels on the left-hand, ſhew the refracted ray of the Sun and Venus at the beginning of the Tranſit; and the two parallel lines, drawn near one another, on the right-hand ſide of the figure, ſhew the ray of the Sun and Venus at the end of the Tranſit, at this place. Therefore, a ſpectator at Tobolſk in Siberia, at the point P, would ſee the Sun at S and Venus at U, at the beginning of their conjunction, in the ray SK, at 7 hours and 28 ſeconds in the morning, under the angle of a ſmall refracted elevating ray; and at 49 minutes 20$\frac{1}{2}$ ſeconds after 12 at noon, the ſpectator at P would ſee the Sun at S and Venus at V, at the beginning of their Egreſs. And as the Sun was then ſo near to the Meridian of that place, he and Venus was under little or no refraction in longitude, at the end of their conjunction.

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Plate 6. Fig. 29.

Again, for ſhewing the obſervation that was taken at Stockholm, from figure 30: this figure in its conſtruction, is to be underſtood, by the deſcription which we gave of the former figure; therefore, the obſerver at Stockholm at the point P, would ſee the Sun at A, and Venus at U, at the time of her Ingreſs on the Sun's diſc, at 3 hours 39 minutes 23 ſeconds in the morning, under a very conſiderable

Plate 6. Fig. 30.

CHAP. XII. angle of the refracted elevating Ray KK; and at 9 hours 30 minutes and 8 seconds, the observer at P would see the Sun at B, and Venus at V, under the angle of a small refracted Ray.

At Stockholm, the total Ingress was observed at about 40 minutes after the Sun arose in the morning; and that place being under an oblique sphere, there was a considerable quantity of Refraction at the beginning of the contact at Stockholm, even greater than at Tobolsk, where the Ingress was at 7 o'clock forenoon. And at Tobolsk (we may say) there was a greater quantity of Refraction than at the Earth's centre, where there is none at all; for the motion of the Sun is understood as seen from the Earth's centre to be uniform, and free from either Parallax or Refraction.

So those who are disposed for deducing the quantity of the Sun's Parallax from the Transits of Venus, in the years 1761 and 1769, if they do justice in it, they must consider and take in the quantity of Refraction, less or more, that the Sun was under, at those places and times of the observations, before they at all can come even near to determine exactly, the Sun's distance from the Earth.

Thus far we have exhibited the method for finding out and determining the Sun's distance from the Earth, in respect of the Moon's distance from it; and also shown the different methods that have been taken by different astronomers for this purpose; and likewise also pointed out wherein they where defective in this respect. And after what has been here described, we leave it to the candid reader, in his studies, to judge (especially those that are conversant in the siderial science) of the propriety of our definiti-

ons. But what we ſhall only here ſay upon it is, that it is moſt agreeable to the doctrine of the Holy Scriptures, that the Earth is fixed and unmoveable. CHAP. XII.

For in the beginning, the Lord made two great lights (viz. the Sun and Moon by way of eminency) the greater light to rule the day, and the leſſer light to rule the night. Now ſince the Moon is called a great light by way of diſtinction, ſhe is greater than one of the ſtars; and as the Sun is but about ſix times more diſtant from the Earth than the Moon is from it, ſhe is not in appearance only but realy greater than one of the ſtars; and no figure can be conſtructed, according to that proportional diſtance of the Sun and Moon, to ſhew that they have an eaſtern courſe, or that the Earth and Moon moves from weſt to eaſt. So our deſcriptions in this treatiſe, are both agreeable to a phyſical principle in nature, and the letter of the Scriptures.

CHAP. XIII.

The Sun and Moon's diſtance from the Earth, depends upon knowing the exact quantity of Refraction, that they are under at the Horizon.

WHAT has been here above ſaid, of the Sun's diſtance from the Earth, that it is about ſix times greater than the Moon's diſtance from the Earth is, take it hypothetically. As both the calculation and conſtruction depends upon the Moon's diſtance from the Earth, and the exact quantity of her Refraction when in the Horizon, and a few times

CHAP. XIII. more, or even leſs, than the diſtance which has been above aſſigned of the Sun and Moon, is not very material in our preſent purpoſe, when we are ſhewing that the Moon is not 400 times nearer to the Earth than ſhe is to the Sun. And ſeeing that there is ſuch a miſtake amongſt the aſtronomers, in not duly conſidering the nature, and likewiſe the manner of Refractions; that although it would operate alike, both on the Sun and Moon, if they were equally diſtant from the Earth, yet the refracted Ray produced to the Sun's orbit in the Horizon, elevates him more there in his orbit, than it does the Moon in her orbit, when they are both in the Horizon, as has been formerly ſhown.

Therefore, we cannot ſo exactly depend upon the preciſe diſtance of the Moon as is given, viz. that ſhe is 60 ſemidiameters of the Earth diſtant from it, or 240 thouſand miles, and that the Moon's horizontal Refraction is 33 minutes and 45 ſeconds; for if her Refraction in the Horizon be leſs than 33 minutes 45 ſeconds, this refracted Ray, produced to the Sun's orbit, will ſhew that the Sun is ſo much more than ſix times the Moon's diſtance from the Earth, and if the Refraction was more than this, the Sun's diſtance would be leſs in proportion. So likewiſe, it follows from this method of taking the Sun's diſtance, that if the Moon were more than 240 thouſand miles diſtant from the Earth, the Sun's diſtance would be underſtood to be ſo much the greater; but if the Moon's diſtance is leſs than 240 thouſand miles, or about 60 ſemidiameters of the Earth, the Sun's diſtance from the Earth will alſo be leſs in proportion, as is evident from the 13 figure formerly deſcribed, which ſheweth in what manner the refracting Ray proceeds

from the Sun and Moon through the air, to a ſpectator on the Earth, when they are both in conjunction in the Horizon at the ſame time. And therefore we have ſtated the Moon's diſtance in the 13 figure at 37 ſemidiameters of the Earth, only by way of hypotheſis; but the 13 figure is too large to be bound in this book.

The Sun or Moon's diſtance are beſt obſerved at the Earth's Equator, when either both or any one of them are in the Equinox. Firſt, becauſe that is a right ſphere, and therefore the Sun and Moon riſe and ſet perpendicular to the obſerver; Secondly, becauſe the parallatic angle is greater there, for the diſtance from thence to the Earth, being greater than upon any parallel of Latitude to the ſouth or north; Thirdly, becauſe at the Equator, the heat is nearly equal every day, that the Refractions are almoſt conſtantly the ſame. And when the Sun and Moon's parallax are taken at the Equator, their diſtance from the Earth is determined very near the truth, if proper allowance is made for the Refraction operating differently upon the Sun and Moon, according to their reſpective diſtances from the Earth.

To repreſent the Sun's diſtance by the Tranſit of Venus exactly, it requires a quadrant to be made ninety foot radius. To repreſent the true diſtance of the Sun by the Tranſit of Venus over his diſc by a full demonſtration, it requires the ſection of a quadrant properly divided into degrees, minutes and ſeconds, and the quadrant muſt be ninety foot radius. And the circle of the Sun's orbit muſt be drawn on the limb of this quadrant, and the circle muſt be ninety foot from the centre; the Earth's diſc in the centre is to be only one inch in diameter, and Venus's

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orbit is to be taken at its proportional diſtance from the Earth, that the Sun's orbit is. Stretch two very ſmall lines from the Earth's diſc in the centre, to the Sun's orbit on the limb of the quadrant, at half an inch diſtance, for the ſenſible and rational Horizon; and an inclining ſmall line between them. For repreſenting the quantity of the Refraction, that the Sun and Venus was under at the Horizon or upwards, put on a piece of paper cut in a circular form for the Sun's effigy, about 32 minutes of a degree in diameter on the Sun's orbit, below the end of the ſmall lines; put alſo a bit of black patcht paper on Venus's orbit, and another very ſmall bit on the Sun's effigy, for repreſenting the planet going over the Sun's diſc during the time of the Tranſit; and when all this is done in a proper manner, it both ſhews the Refraction that the Sun and Venus was under at the time of the Tranſit, and alſo determines the Earth's parallax within two ſeconds very plainly.

CHAP. XIV.

Of the Doctrine of the Sphere, and Circles thereof deſcribed.

HAVING ſhewn the method for finding the Sun's diſtance from the Earth, we come to ſpeak a little of the doctrine of the Sphere, and the order by which the Sun, Moon and Stars, move and circulate in the firmament of heaven.

By the doctrine of the Sphere, is meant the ſolution of ſuch problems as relate to the heavens, or concavity of the viſible world, in meaſuring the circles

thereof, and angles which they make with each other. I shall shew in a method as concise as I can, according to this scheme of astronomy.

CHAP. XIV.

The Horizontal circle.

The Horizon is one of the six great circles of the Sphere, which divides the Heavens and the Earth into two equal parts, or hemispheres, distinguishing the upper from the lower. It is either sensible or apparent, or rational or true Horizon. The sensible or visible Horizon is that circle which limits our sight, and may be conceived to be made by some great plain on the surface of the Earth or Sea: it determines the rising and setting of the Sun, Moon or Stars in any particular Latitude. The rational, or real, or true Horizon, is a circle which encompasses the earth exactly in the middle. And there are two Poles of the Horizon, the one is a point of the Heavens which is directly over the head of the spectator, and is called the Zenith; the other directly opposite under his feet, is named the Nadir.

The Equinoctial.

The Equinoctial in the Heavens, or Equator on the Earth, is another of the six great circles of the Sphere, whose poles are the poles of the world. It divides the globe into two equal Hemispheres, viz. north and south, and passeth through the east and west points of the Horizon, and at the Meridian it is always raised so much as is the compliment of the Latitude of the place where you are, which arch is also equal to the arch of the Meridian, between the Zenith of any place and Pole. Every 15 degrees of this circle, that passeth by the Meridian by a diurnal motion, is equal to one hour in time. When the Sun comes to this circle, which is about the 20th of March, and the 23d of September, he makes the days and nights equal, all the world over, except under the Poles.

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And all the Stars and every point of the Heavens, except the two Poles, describe by their revolutions either this circle or a lesser parallel to it, which circles are either bigger or lesser, according as the Stars which describe them, are more removed or nearer to the Poles.

The Ecliptic.

The Ecliptic is also one of the six great circles of the Sphere, intersecting the Equinoctial in two opposite points, Aries and Libra, making an angle therewith of 23 degrees 29 minutes, called the obliquity of the Ecliptic, equal to the Sun's greatest declination. The obliquity of the Ecliptic was determined thus:

	deg.	min.
At Glasgow, the height of the North Pole is	55	50
When the Sun enters Cancer, his Meridian altitude there is	57	39
When the Sun enters Capricorn, his Meridian altitude there is	10	41
The difference of Meridian altitude is	46	58
The half is the obliquity of the Ecliptic, or distance of the Pole of the Equinoctial from the Pole of the Ecliptic, equal to the Sun's greatest declination.	23	29

The Ecliptic is divided into twelve equal parts, which are called the Twelve Houses or Signs, and they have their names from the neighbouring Constellations. They begin at the Vernal Intersection of the Equator and Ecliptic, and are reckoned from the west eastwards, according to the order in which the Sun falls backward, among the Stars in the Ecliptic,

in their diurnal motion around in the Heavens. The firſt three ſigns are ♈ ♉ ♊ which ariſes from the Equinoctial, and aſcend northwards to the point of the Summer Solſtice; the next three are ♋ ♌ ♍ which begin from Cancer, and deſcend again towards the Equinoctial, till they come to the Autumnal Interſection; the third ternary of ſigns conſiſts of ♎ ♏ ♐ which begin at Libra, and departing from the Equinoctial Southward, reach to the Winter Solſtice; ♑ ♒ ♓ make the fourth, which begin at Capricorn and end in the Vernal Equinox. Each ſign is divided into 30 degrees, and conſequently the whole Ecliptic into 360 degrees; altho' the Sun and ſtars move round the Earth every day, yet the Sun moves about in ſpiral lines, ſo as to viſit both the Tropics of Cancer and Capricorn once every year, and being ſo much ſlower than the ſtars in the Ecliptic, he loſes one circulation of them annualy; the Sun is always obſerved in this circle, and never in the leaſt deviates from it, as the Planets do, which go ſome times on one ſide, and ſome times on the other ſide of it, through a ſpace of about eight degrees. And therefore, if we imagine a broad circle or zone of about ſixteen degrees in breadth, which the Ecliptic cuts in the middle, this will be the ſpace wherein the Planets perform both their real and relative motions, which is called the Zodiac, or ſign-bearer, becauſe of the ſigns placed in it. Eleven of theſe twelve repreſent living creatures, viz. all but Libra, the balances. For the reſt, are the Ram, the Bull, the two naked Boys, the Crabfiſh, the Lion, the Virgin, the Scorpion, the ſhooting Horſe-man, the Goat, the Water-bearer, and the two Fiſhes.

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The Meridian.

The Meridian is another of the ſix great circles of

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the Sphere, paſſing through both the Poles of the world, and cutting the Equinoctial and Horizon at right-angles, being equally diſtant between the eaſt and weſt, unto which, when the Sun, or any Star comes, it is the higheſt, or has then the greateſt Altitude that it can have that day in that Latitude. The Stars are then ſaid to culminate or be ſouth when they are upon the Meridian, ſo likewiſe they are at their greateſt depreſſion below the Horizon when they arrive at the ſame Meridian. And becauſe the Sun every day deſcribes ſome parallel by his diurnal motion, when the Sun comes to the Meridian at any time it will be mid-day, and mid-night when he arrives at the ſame Meridian below the Horizon, and from thence this circle has its name. Since every Meridian finiſhes its circulation round the Earth, or 360 degrees in twenty-four hours, it muſt each hour have an angular motion of 15 degrees, which is the 24th part of 360. If through the Poles, and every 15th degree of the Equator, we conceive a circle to paſs, they are called Horary circles, and they will divide the Equinoctial into 24 equal parts, and each of them in its order will determine the hours that is to be reckoned in a place, when the plane of the Meridian of that place comes to coincide with that circle.

The two Colures.

There are two great circles called Colures, which interſect one another at right angles in the Poles of the world, and divide the Zodiac into four equal parts, and denote the four ſeaſons of the year. That paſſing thro' Aries and Libra, is called the Equinoctial Colure, and the other which cuts the former at right-angles and paſſes thro' Cancer and Capricorn, is called the Solſtitial Colure; becauſe it interſects the Ecliptic at the points which are at the greateſt diſtance from

the Equator, to which when the Sun comes, he does not ſenſibly for ſome days change his declination; and therefore theſe points are called Solſtices. CHAP. XIV.

There are two leſſer circles of the Sphere parallel to the Equinoctial, and 23 degrees 29 minutes diſtant therefrom, being the bounds or limits of the Sun's greateſt declination, north or ſouth; that which between the Equinoctial and the North Pole is called the Tropic of Cancer, and the other between the Equinoctial and South Pole the Tropic of Capricorn. When the Sun hath arrived at the Tropic of Cancer, which is about the 22d of June, he maketh the longeſt days to all the northern inhabitants of the world, and returning towards the Equinoctial, when being arrived at the Tropic of Capricorn, which is about the 21ſt of December, he then makes the longeſt nights and ſhorteſt days to all that dwell on the north ſide of the Equator; and to thoſe that live in ſouth Latitudes juſt the contrary appearances.

The Tropical Circles.

There are other two remarkable leſſer circles of the Sphere, which are parallel to the Equinoctial, and theſe are deſcribed by the apparent diurnal motions of the two Poles of the Ecliptic round the Poles of the Equinoctial, from which they are diſtant 23 degrees 29 minutes. They are called the two Polar Circles; this on the northern Sphere is named the Arctic Circle, from the two Bears that lie near it; the other circle on the South is called the Antartic, or circle oppoſite to the Arctic.

The Polar Circles.

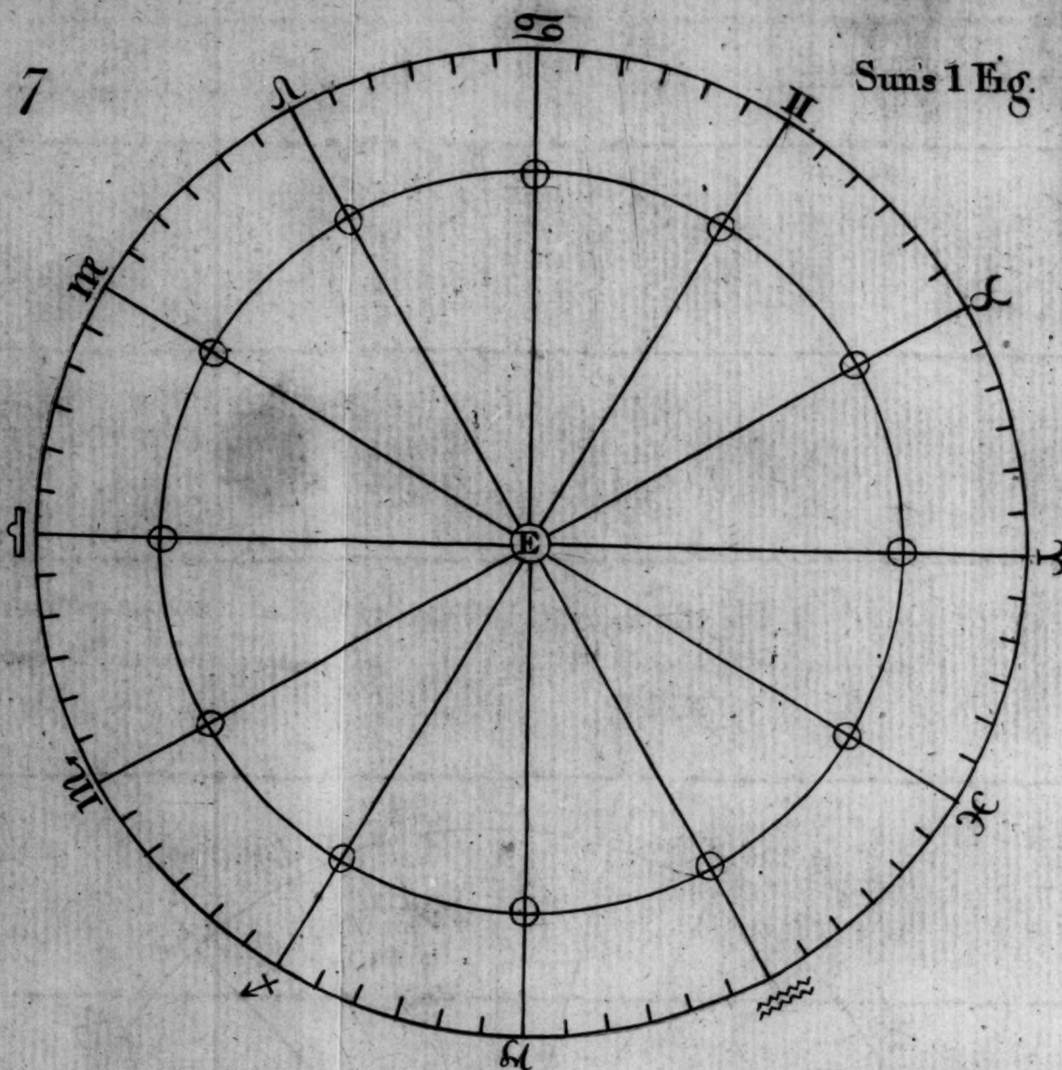
There are two Poles of the Horizon, the one is the point of the Heavens which is directly over the head of the ſpectator, and is called the Zenith; the other directly oppoſite under his feet, is named the Nadir; and innumerable circles thro' thoſe Poles to the Ho-

CHAP. XIV. rizon are ſtyled Vertical Circles or Azimuths. Among them there are two particularly remarkable, one of which is the Meridian, and the other is the Prime Vertical; the firſt paſſes thro' the Poles of the Equator and the Zenith, and cuts the Horizon in the points of north and ſouth; the other paſſing thro' the Zenith cuts the other at right angles, and marks on the Horizon the points of eaſt and weſt. Theſe circles divide the Horizon at their interſections with it, into four quarters, each of which is again ſubdivided into eight parts; and conſequently, the whole Horizon is divided into thirty-two parts, which are called the Rumbs or points of the compaſs.

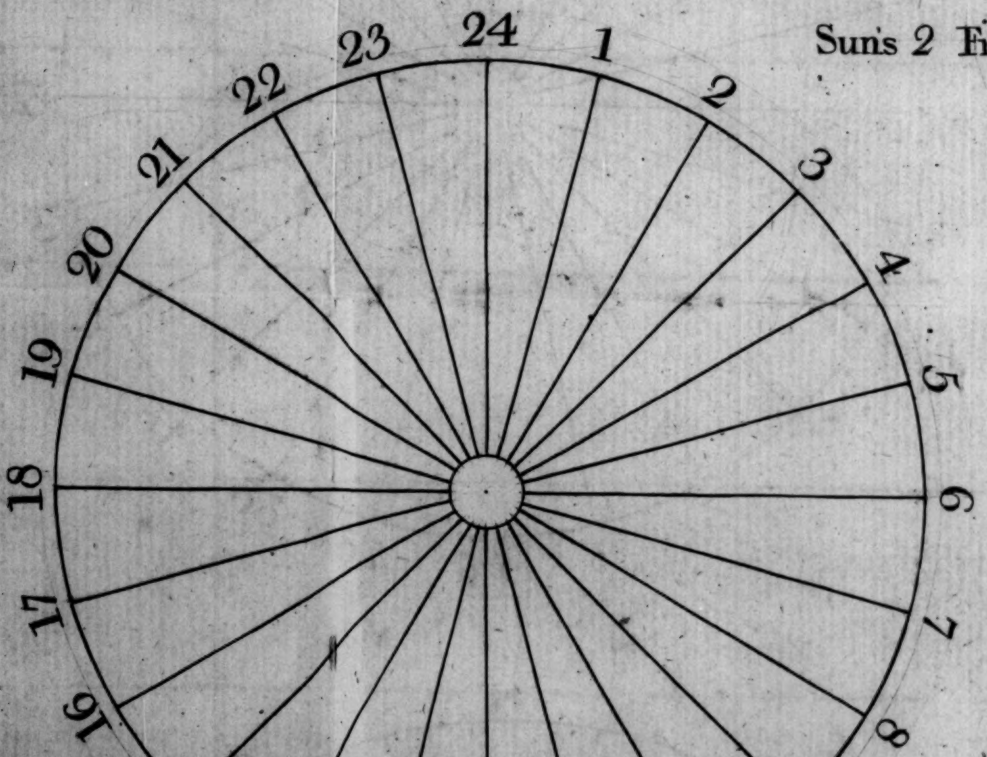
Since the Sun finiſhes his circulation round the Earth in twenty-four hours, whoſe Equator is divided into 360 degrees, he muſt each hour have an angular motion of 15 degrees, which is the twenty-fourth part of 360; conſequently, every 15 degrees of weſt Longitude from the firſt Meridian, they have their noon one hour later than the Meridian to the eaſt of them.

In any place of the Terraqueous Globe, the height of the Pole above the Horizon is equal to the Latitude of the place. Hence we have a method of meaſuring the circumference of the whole Earth, and of knowing how many miles it is round about the Earth. For if we go directly northward until the Pole be elevated one degree higher, and then if we meaſure the length of the way we have gone northward, and have the number of miles it contains, we ſhall have the number of miles in a degree of a great circle of the Earth's globe; and this number multiplied by 360, the degrees in whole Periphery, it will give the length of the circumference of the Earth in miles. By very accurate obſervations, the length of a degree is found

Suns 1 Fig.



Suns 2 Fig.



to be 69 Engliſh miles, which was commonly reputed to be only 60 miles. CHAP. XV.

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Shewing the order by which the Sun proceeds through the ſigns of the Zodiac, by falling back in the ſigns from weſt to eaſt.

WE come to ſhew the order by which the Sun proceeds through the ſigns of the Zodiac, according to the order of his courſe, as he is retrograde and falls back in the Signs from weſt to eaſt, as it is here repreſented by figure 1. The Sun enters into the firſt degree of Aries upon the 20th day of March, and he enters into the firſt degree of Taurus upon the 20th day of April; he enters alſo into the firſt degree of Gemini, upon the 21ſt day of May. Further, he enters into the firſt degree of Cancer, upon the 21ſt day of June; and he enters into the firſt degree of Leo, upon the 23d day of July. Likewiſe, into the firſt degree of Virgo, upon the 23d day of Auguſt; and alſo into the firſt degree of Libra, upon the 23d day of September. And again, he enters into the firſt degree of Scorpio, upon the 23d day of October; into the firſt degree of Sagittarius, upon the 22d day of November. Further, into the firſt degree of Capricorn, upon the 21ſt day of December; and into the firſt degree of Aquarius, upon the 20th day of January. And laſtly, he enters into the firſt degree of Piſces, upon the 18th day of February, which compleats one circulation of the Sun in paſſing

Plate 7. The Sun's Fig. 1.

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through the Signs of the Zodiac. This firſt figure is eaſily underſtood. For the earth is placed in the centre, and the Sun is marked on the Radius lines through the firſt degree of every one of the twelve Signs of the Zodiac, according to their order; and ſhews how the Sun loſes one circulation of the Stars in a year.

We alſo ſhew the manner of the Sun's viſible diurnal motion around the Earth from eaſt to weſt, as proceeding in the equator. Let figure 2, by its Radius lines, repreſent the 24 Meridians over which the Sun paſſes once every day, from 1 o'clock all round to 24. This figure repreſents the Sun as moving uniform by equal ſpaces in equal times. But though the Sun be perfectly equable in his motion, yet he neither moves equally in the Equator, nor does he appear to be ſo; which ariſes from two cauſes, viz. the obliquity of the Ecliptic to the Equator, and the Sun's anomaly. But theſe are beſides my preſent purpoſe here to explain.

Plate 7. Sun's Fig. 2.

We ſhall now ſpeak a little of the Motion of the Stars, and how much they gain upon the Sun in their courſe for a day or a year. For as the Sun in the Heavens is the grand regulator of our time upon Earth, ſo it is by the mean motion of the Sun, that we come to regulate our calculations of all other motions of the Stars or Planets. For, according to the Sun's mean motion around the Earth, from any particular Meridian to the ſame Meridian again, it makes one day or 24 hours. But the Stars revolve about the Earth, from any particular Meridian to the ſame Meridian again, in the ſpace of 23 hours 56 minutes and 4 ſeconds. And ſo by their accelerations they gain upon the Sun 3 minutes and 56 ſeconds every

day, which amounts to one diurnal revolution in a year. And therefore, in 365 days, as measured by the return of the Sun to the Meridian, there are 366 days as measured by the Stars returning to it. The former are called Solar days, and the latter Syderial days. CHAP. XV.

And when the Sun departs from any Equinoctial or Solstitial point, and arrives at the same point again, he finishes, what we call the Tropical year, which by observation is found to contain 365 days 5 hours 48 minutes and 57 seconds. And when he arrives at the same Star again, as seen from the Earth, he compleats the Syderial year, which contains 365 days 6 hours 9 minutes and $14\frac{1}{2}$ seconds. The Syderial year is therefore 20 minutes $17\frac{1}{2}$ seconds longer than the Solar or Tropical year; and 9 minutes $14\frac{1}{2}$ seconds longer than the Julian or Civil year, which we state at 365 days and 6 hours. So that the Civil year is almost a mean betwixt the Syderial and Tropical year.

And therefore, when the Sun sets out as from any given or fixed point in the Heavens, the moment when he is departing from the Equinoctial, or from either Tropic, he will come to the same Equinox or Tropic again, 20 minutes $17\frac{1}{2}$ seconds of time, or 50 seconds of a degree, before he compleats his retrograde course, so as to arrive at the same point or star from whence he set out.

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THE Moon is a planet revolving about the Earth diurnally, from the Meridian to the Meridian

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again, in the ſpace of 24 hours and 48 minutes; and from change to change in 29 days 12 hours and 44 minutes; becauſe ſhe loſes on circulation of the Sun in that ſpace of time; and of the Fixed Stars, ſhe loſes a circulation in 27 days 7 hours and 43 minutes.

The Moon is an opaque globe, and ſhines only by reflecting the light of the Sun; therefore whilſt that half of her which is towards the Sun is enlightened, the other muſt be dark and inviſible. Hence, ſhe diſappears when ſhe comes between the Sun and us; becauſe her dark ſide is then towards us. And when ſhe is gone a little way forward, we ſee a little of her enlightened ſide, which ſtill increaſes to our view as ſhe advances backwards and falls behind the Sun, until ſhe comes to be oppoſite to the Sun, and then her whole enlightened ſide is towards the Earth; and then ſhe appears with a round illuminated Orb, which we call the full Moon, her dark ſide being then turned away from the Earth. From the full ſhe ſeems to decreaſe gradually, as ſhe goes through the other half of her courſe, ſhewing us leſs and leſs of her enlightened ſide every day, till her next change, or conjunction with the Sun, and then ſhe diſappears as before.

This continual change of the Moon's phaſes, demonſtrates that ſhe ſhines not ſo as to enlighten the Earth by any light of her own; for if ſhe did, being globular, we would always ſee her with a round full orb like the Sun. But whether the Moon's body be altogether inviſible in itſelf on that ſide which is turned from the Sun, or if ſhe hath as much innate natural brightneſs of herſelf as to make her viſible, ſo as to be ſeen, is a queſtion. For, even in total Eclipſes, we can ſee the Moon's body of a tarniſhed copper

P. 8

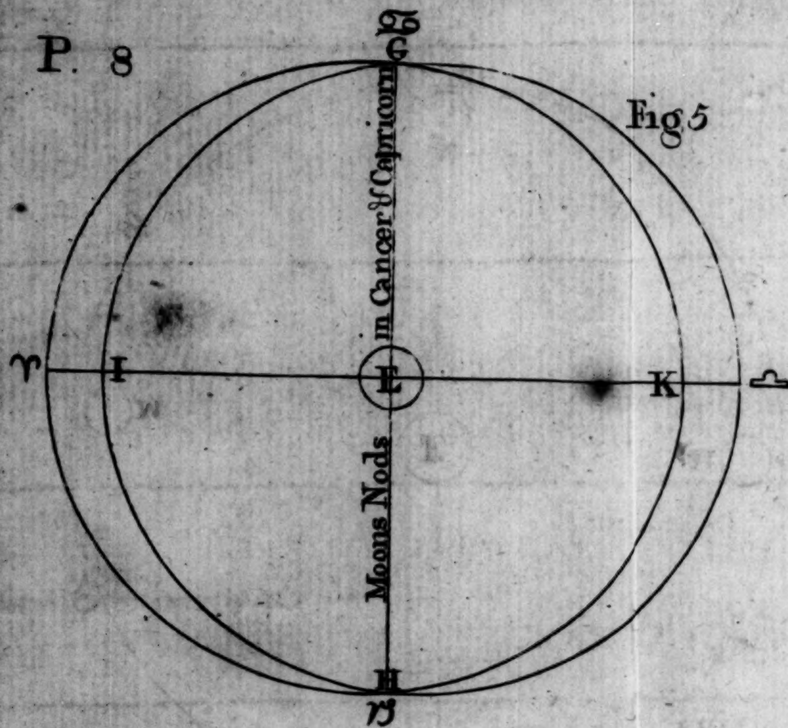

Fig. 5

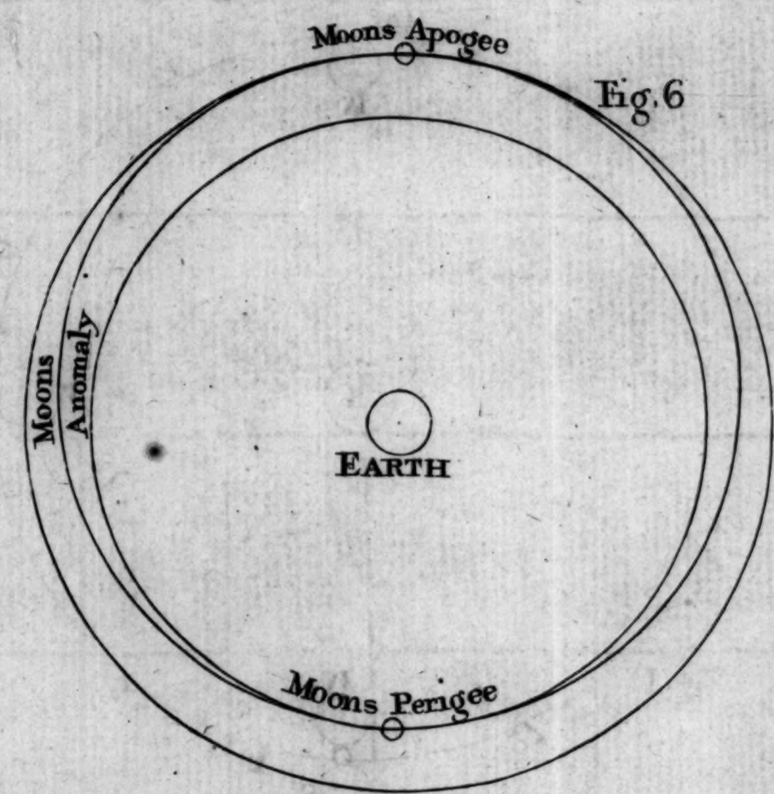

Fig. 6

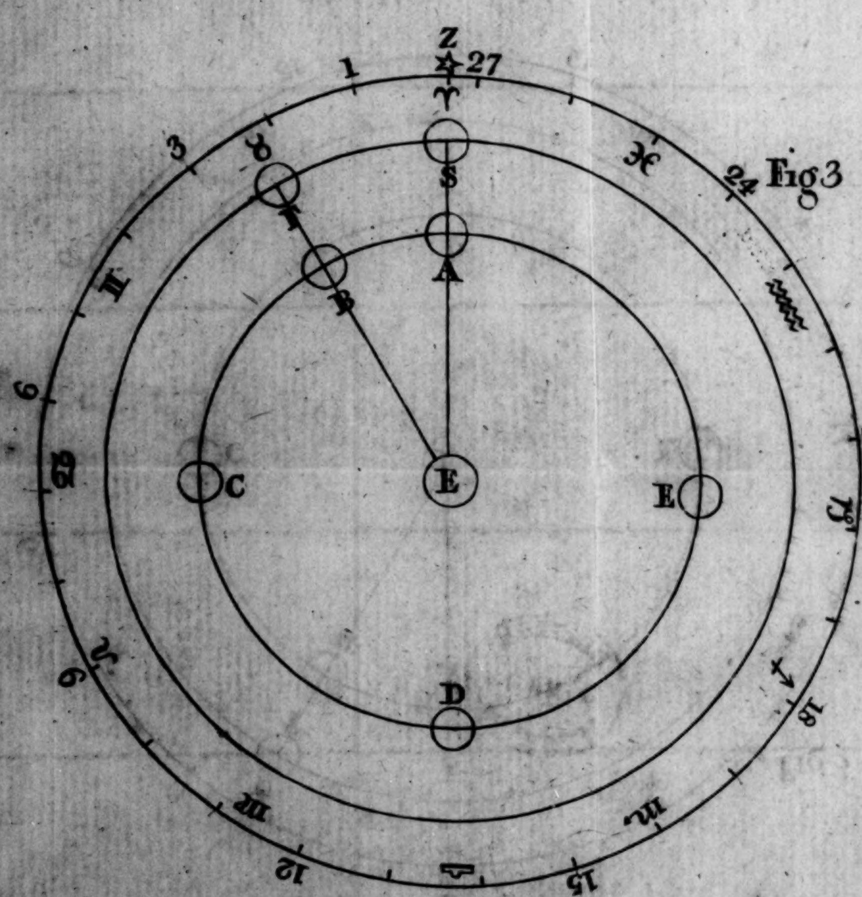

Fig. 3

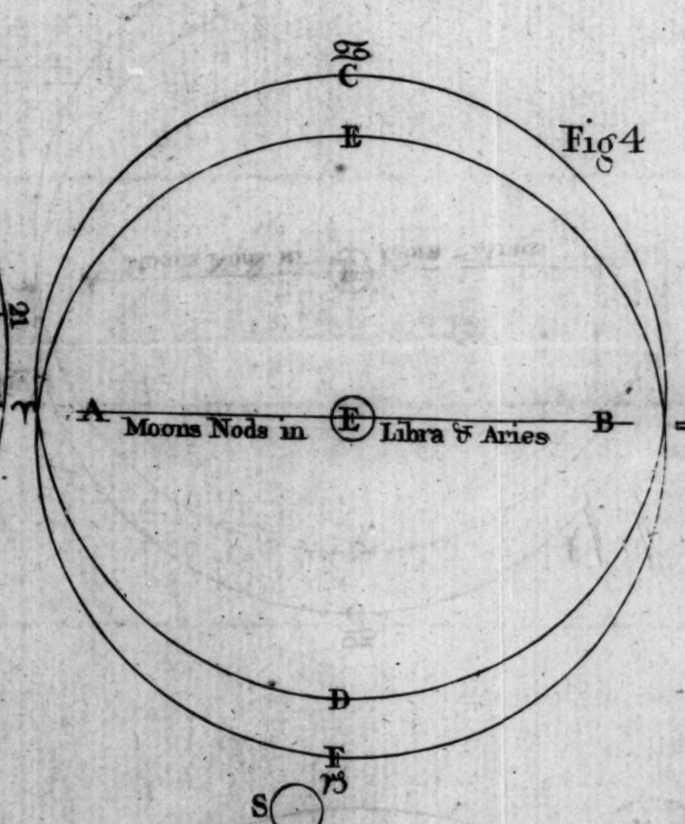

Fig. 4

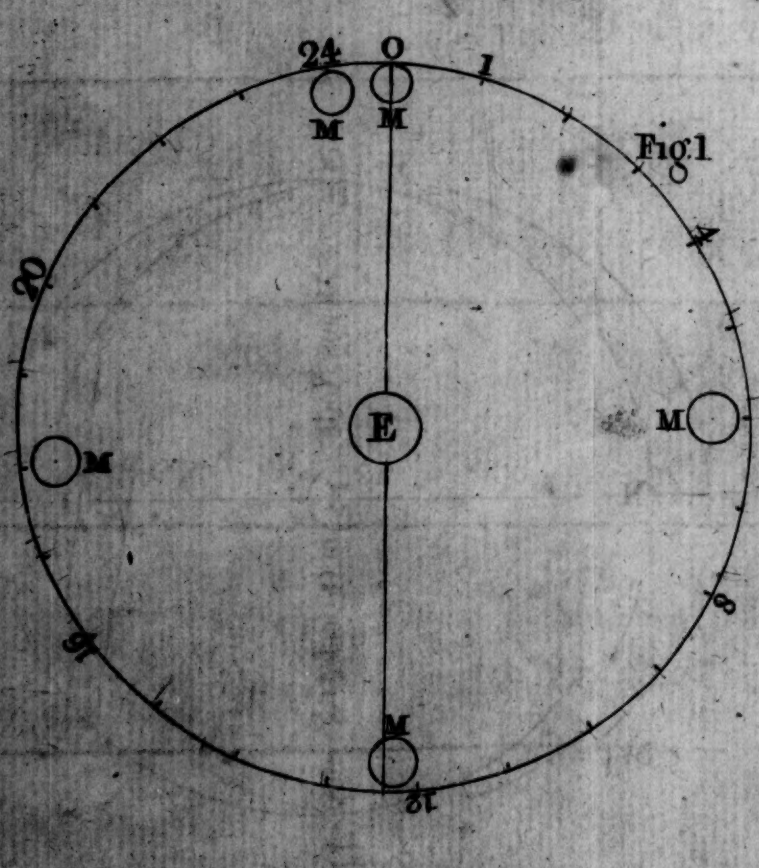

Fig. 1

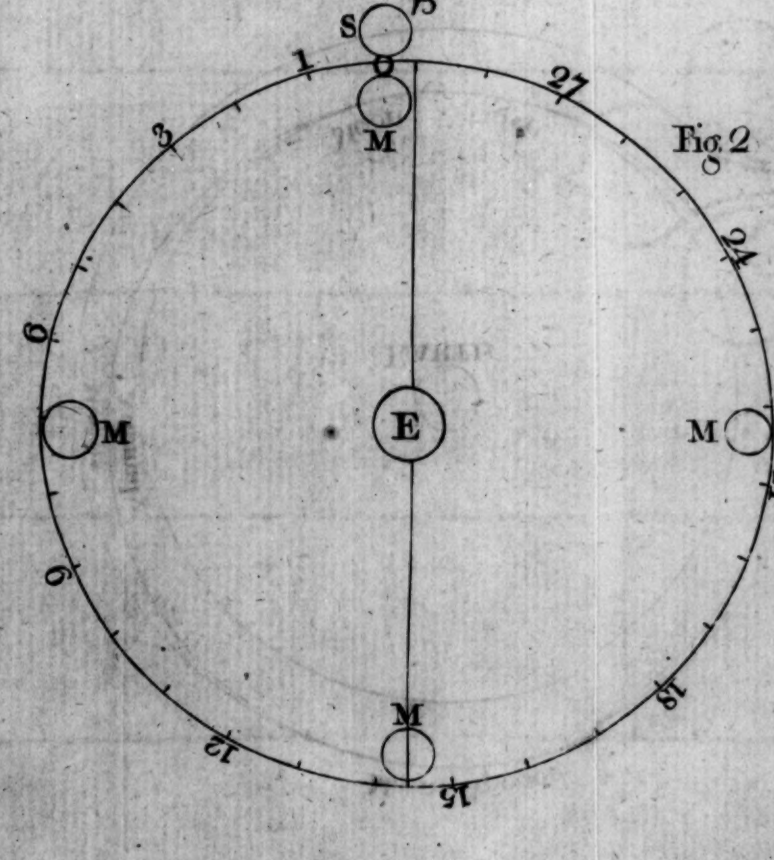

Fig. 2

colour; and before and after the changes, besides the bright shining horns, we can perceive the rest of her body behind them, though but darkish and obscure. Some are of opinion, that the Moon derives this light from the Planets and Stars; and others, that it proceeds from the Earth's atmosphere, that reflects and turns the Sun's rays upon the Moon's body. Yet I would incline to think, that the Moon has some natural light of her own, or native brightness, so as to make her to be visibly seen.

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The Moon revolves about the Earth, from east to west, in 24 hours and 48 minutes, as in figure 1. When the Moon is on the Meridian as at o, she proceeds in her course from the Meridian at o to 1, 2, 3, 4, 5, and so on to 24; and when at 24, she wants 48 minutes of time to bring her to the same Meridian again. And because the Sun revolves about the Earth, from any one Meridian to the same again, in 24 hours; and the Moon taking 48 minutes of more time to make a compleat circulation, is the cause why the Moon loses a compleat circulation of the Sun in 29 days 12 hours and 44 minutes, at a mean rate.

Plate 8. The Moon's 1st Fig.

Let the Sun and Moon be in conjunction, in any one certain Meridian, as in figure 2 at o, and the Sun's velocity being accelerated 48 minutes each day, in his revolving about the Earth from east to west, more than the Moon is, the Moon of consequence, falls behind the Sun towards the east, from the Meridian at o to 1, 2, 3, 4, 5, 6, and so on to 29, round to the Meridian at o to another conjunction, in the space of 29 days and about a half. As this figure sheweth where the Earth is placed in the centre, the Moon on the inside of the circle, and the Sun is placed on the outside of the same circle, and the numeral

Plate 8. The Moon's 2d Fig.

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Figures all round the circle, ſhew the number of days between one conjunction to another.

As the Sun circulates about the Earth in 24 hours, the Moon in 24 hours and 48 minutes, and the fixed Stars in the ſpace of 23 hours 56 minutes and 4 ſeconds of time, as meaſured by the Sun's mean motion. So when the Moon is in conjunction on the Meridian with any fixed Star, in 24 hours time afterward, ſhe will fall behind the ſame Star 51 minutes and 56 ſeconds of time: and ſo much ſhe falls behind the Stars each day. And ſo of conſequence by this, the Moon loſes one circulation of the fixed Stars in the ſpace of 27 days 7 hours and 43 minutes, which is called a periodical month. In which ſpace of time, the Moon viſits both the Tropics, and falls back in her retrograde courſe through all the ſigns of the Zodiac, although ſhe takes 29 days and a half, between one conjunction with the Sun and another; which is called a Synodical month or Lunation.

Plate 8. The Moon's 3d Fig.

Therefore to exhibit both theſe, as by figure 3. Let E be the Earth in the centre, and A the Moon in her Orbit, S the Sun, and Z a Star in the Zodiac, all in their different orbits one above another. Then, ſuppoſe the Moon at A, the Sun at S, and the Star in Aries at Z, to be all in conjunction, ſo the Moon by loſing 51 minutes and 56 ſeconds of the Star every day, will fall behind the Star to the eaſt, and will be retrograde, as from A to B, from B to C, from C to D, from D to E, and from E to A again, in 27 days 7 hours and 43 minutes, when ſhe will come again to be under the ſame Meridian with the Star as before. But as the Moon loſes but 48 minutes of the Sun, each day in his courſe, and the Sun loſes 3 minutes and 56 ſeconds of time of the Star in its courſe, when the

Moon at A has fallen back in her courſe to A again, and come under the ſame Meridian with the Star, ſhe is not come to a conjunction with the Sun. For the Sun, in that ſpace of time, has fallen back behind the Star, almoſt a whole ſign towards the eaſt, as from S to F. Therefore, when the Moon has again arrived at the point at A, ſhe will not yet be ſeen in conjunction with the Sun, but muſt yet further fall back, as from A to B, in her orbit. And when at B ſhe is ſeen in conjunction with the Sun at F; ſo that when the Moon has been under the ſame Meridian with the Sun, and a certain Star, and after the Moon has fallen back to the Meridian with the ſame Star again, it requires 2 days and 5 minutes time more before ſhe come to a conjunction with the Sun, as the figure ſheweth, according to their middle motion. CHAP. XVI.

Hitherto the motions of the Moon, in her Orbit, are plain and eaſy to be underſtood; becauſe we have ſuppoſed the Moon to move in the Ecliptic, from which the Sun never deviates. But the orbit in which the Moon realy moves, is different from the Ecliptic; one half being elevated 5 degrees and 18 minutes above it, and the other half as much depreſſed below it. The Moon's orbit, therefore, interſects the Ecliptic in two points, diametrically oppoſite to each other; and theſe interſections are called the Moon's Nodes. So the Moon can never be in the Ecliptic but when ſhe is in either of her Nodes, which is at leaſt twice in every courſe, from change to change, and ſometimes thrice. For as the Moon goes almoſt a whole ſign more than round her Orbit, from change to change, if ſhe paſſed by either Node about the time of change, ſhe will paſs by the other in about 14 days after, and come round to the former

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Node, two days again before the next change. That Node, from which the Moon begins to aſcend northward, or above the Ecliptic, in north Latitudes, is called the aſcending Node, and head of the Dragon; and the other, the deſcending Node, or tail of the Dragon; becauſe when the Moon paſſes by it, ſhe deſcends below the Ecliptic ſouthward.

If the plane of the Moon's Orbit coincided with the plane of the Ecliptic, that is, if the Sun and Moon moved both in the ſame plane, the way of the Moon in the Heavens, ſeen from the Earth, would be exactly the ſame with the circle that the Sun doth deſcribe; only the Sun would be obſerved to deſcribe that circle in the ſpace of a year, which the Moon does in a month. Now, in reality, the plane in which lies the Moon's Orbit, is not coincident with the plane of the Ecliptic; but theſe two planes cut one another in a right line, which paſſes through the centre of the Earth.

Plate 8. The Moon's 4th Fig.

In figure 4, Let the Earth be in the centre, and AB the Equinoctial, EF the Ecliptic, and CD the Orbit of the Moon in the Zodiac, and the line of Nodes in Aries and Libra in the Equinoctial, and the aſcending Node northward at A in Aries, and the deſcending Node ſouthward at B in Libra. In this ſituation of the Nodes, the Moon's Orbit aſcends and is elevated 5 degrees and 18 minutes above the Ecliptic in north Latitudes; and the inclination of the Moon's Orbit, with the Equinoctial, as ſhewn by the place of her aſcending north Node in Aries, is 28 degrees 46 minutes and 20 ſeconds. If the line of Nodes were immoveable, it would always look to the ſame point of the Ecliptic; but it is found by obſervation, that this line of the Nodes does conſtantly

change its place, and ſhifts its ſituation from eaſt to weſt, contrary to the order of the Signs, and by a retrograde motion finiſhes its circulation all round the Ecliptic in the ſpace of 18 years and 225 days. After which time, either of the Nodes having receded from any point of the Ecliptic, returns to the ſame again; and when the Moon is in the Node ſhe is alſo ſeen in the Ecliptic.

Hence, it is evident, that the Moon can never be obſerved preciſely in the Ecliptic, but twice in every period, that is when ſhe enters the Nodes; when ſhe is in any other place of her Orbit, ſhe deviates from it, and is ſometimes nearer, and ſometimes further removed from the Ecliptic, according as ſhe happens to be nearer or further off from the Nodes. But ſhe is at her greateſt diſtance from the Nodes when ſhe is in the points of her Orbit E or D, which are the middle points between the Nodes, and theſe points are called the limits. The diſtance of the Moon from the Ecliptic is called her Latitude, which is meaſured by an arch of a circle drawn through the Moon perpendicular to the Ecliptic, the arch of which circle, intercepted between the Moon and the Ecliptic meaſures the Moon's Latitude, or her diſtance from the Ecliptic; and therefore, ſuch circles perpendicular to the Ecliptic, are called circles of Latitude. The Latitude of the Moon, when it is at the biggeſt, as in C or D, does never exceed 5 degrees and about 18 minutes, which Latitude is the meaſure of the angles at the Nodes.

And, according as we have before ſaid, that obſervation teſtifies that the line of the Nodes does conſtantly change its place, and ſhifts from eaſt to weſt, in the ſigns, 19 degrees and 40 minutes every year;

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and compleats its circulation all round the Ecliptic, in the ſpace of 18 years and 22 days.

We ſhall next ſhew the inclination of the Moon's Orbit with the Equinoctial, when her Nodes are in Cancer and Capricorn, when this line cuts the other at right angles, that is in a ſquare with the former poſition of the Nodes, by the 5 figure here. In this figure, Let I K be the Equinoctial and G H the line of Nodes in Cancer and Capricorn; in this poſition of the Nodes the inclination of the Moon's Orb with the Equinoctial is 23 degrees and 29 minutes, juſt equal to the inclination of the Ecliptic with the Equinoctial. But when the deſcending Node of the Moon is in Aries, as in underſtanding the lines in figure 4 the reverſe way, the inclination of the Moon's Orb with the Equinoctial is 18 degrees 11 minutes and 40 ſeconds; and when the Moon's aſcending Node is in Aries, the inclination of her Orbit with the Equinoctial is 28 degrees 46 minutes and 20 ſeconds; and when the Node is in Cancer or Capricorn, the inclination is 23 degrees 29 minutes; but when the deſcending Node comes to Aries, the inclination of her Orbit with the Equinoctial is only 18 degrees 11 minutes and 40 ſeconds.

Plate 8. The Moon's 5th Fig.

The 4th Fig.

After having deſcribed theſe regulations in the Lunar motions, we ſhall next ſpeak of another of the laws by which the Moon's motions are regulated. Obſervations have diſcovered to us, that the diſtance of the Moon from the Earth does conſtantly change, ſometimes the Moon comes nearer to us, ſometimes ſhe goes further from us. And when the Moon is at her greateſt diſtance from the Earth, ſhe is then ſaid to be in her Apogeon; and when ſhe comes to the point of her Orbit neareſt the Earth, it is called the

Perigeon. When the Moon is in the Apogeon, her diameter ſubtends an angle of 29 minutes and 48 ſeconds; but when ſhe is in the Perigeon, ſhe is ſeen under an angle of 33 minutes and 18 ſeconds.

It is alſo obſerved, that the Moon goes through her Orbit, from her Apogee to her Apogee again, in 27 days 13 hours 18 minutes and 43 ſeconds, at a mean rate. And as the Earth is the centre of the Moon's Orbit, ſuch as is repreſented by figure 6, where the Earth is placed in the centre, the inmoſt circle ſheweth the diurnal courſe of the Moon about the Earth when ſhe is in the Perigeon, and the outmoſt circle her courſe when ſhe is in the Apogeon; and the circle of elevation between them, ſhews the order of the Moon's elevation from the Perigee towards the Apogee, and her deſcending from the Apogee to the Perigee again. Plate 8. The Moon's 6th Fig.

The Moon's diſtance from the Earth, when in the Apogee, is about a tenth part greater than when ſhe is in the Perigee, or as 30 is to 33 nearly, whence the motion of the Moon about the Earth is quickeſt in the Perigeon, and ſloweſt in the Apogeon.

And as it is obſerved that the Moon goes through her Orbit, from any given fixed Star to the ſame Star again, in 27 days 7 hours 43 minutes and 4 ſeconds, at a mean rate; from her Apogee to her Apogee again, in 27 days 13 hours 18 minutes and 43 ſeconds; and from the Sun to the Sun again, in 29 days 12 hours and 44 minutes. This ſhews that the Moon's Apogee moves in the Ecliptic, from the weſt towards the eaſt, and that at a much quicker rate than the Sun's Apogee does, ſince the Moon is 5 hours 55 minutes and 33 ſeconds longer in revolving from her Apogee to her Apogee again, than from any Star

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to the ſame Star again. Therefore, the Moon's Apogee has an angular motion round the Earth from the weſt towards the eaſt, according to the order of the Signs, in the ſpace of 8 years and 312 days.

Plate 22. The Moon's 7th Fig.

And as the Moon's motion is quickeſt, when ſhe is in the Perigeon, and sloweſt in the Apogeon, ſo this is repreſented and ſhewn by figure 7, where the Earth is in the centre at E, the outmoſt circle is the Zodiac among the Stars, and the inmoſt circle repreſents the Moon's circle of elevation in her gradual aſcending from the Perigee to the Apogee, and her deſcending to the Perigee again, as was ſhown in the 6th figure, by the inclining circle between the Moon's loweſt and higheſt circles of her elevation, as ſhe revolves diurnally around the Earth. The point P is called the Moon's Apogee, becauſe when ſhe is there, ſhe is at her greateſt diſtance from the Earth; the point R her Perigee, becauſe when ſhe is in it, ſhe is then at her leaſt diſtance from the Earth. The Zodiac circle is equally divided by 12 points or letters, ABCDE, and ſo all round to M on the inſide of the circle. The Moon's circular gradation round from the Apogee to the Apogee again, is alſo equally divided by 12 lines, which are produced to the Zodiac at the points ABCDE &c. all round to M, as marked on the outſide cf the circle.

Now, Let the Moon be in the Apogee at the point P, at her greateſt diſtance from the Earth, as ſeen in the Zodiac at A, and as ſhe proceeds from P about to R, in her way to the Perigee, ſhe is ſeen at B, a little ſhort of the *b* in the Zodiac, and ſo on; likewiſe, from BCDEF till ſhe come to G, ſhe loſes ſomewhat of the points *cdef*, and when ſhe is at G, the point on the Moon's Orbit and the Zodiac point

are equal. Again, as the Moon proceeds from the Perigee at R to the Apogee, and when ſhe is ſeen at H ſhe is a little before the point *h* in the Zodiac; and ſo alſo at the lines IKLM ſhe is a little before the points *iklm*; and when ſhe returns all round again to P in the Apogee, ſhe is ſeen at the point A in the Zodiac, which ſhews that the motion of the Moon is quickeſt in the Perigeon, and ſloweſt about the Earth in the Apogeon. The difference is ſo great, that ſhe is ſometimes in conjunction with the Sun, or in oppoſition to him, ſooner by 9 hours 47 minutes and 54 ſeconds, than ſhe would be if her motion were equable, and at other times as much latter; therefore the Aſtronomers conſtructed a table ſo as to anſwer all the various inequalities, depending upon the different eccentricities of the Moon's orbit, in the Syzygias, and is called the ſecond Equation of the mean to the true Syzygia.

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Plate 22. The Moon's 7th Fig.

We have now ſhewn the time that the Moon takes in revolving diurnally around the Earth, from the Meridian to the Meridian again, being 24 hours 48 minutes; from any given fixed ſtar to the ſame ſtar again, in 27 days 7 hours 43 minutes and 4 ſeconds, at a mean rate; from the Sun to the Sun again, in 29 days 12 hours 44 minutes and three ſeconds; from her Apogee to her Apogee again, in 27 days 13 hours 18 minutes and 43 ſeconds. And as the Moon's Orbit croſſes the Ecliptic in two oppoſite points, which are called her Nodes, it is obſerved that ſhe revolves from any Node to the ſame Node again, in 27 days 5 hours 4 minutes 37 ſeconds, which ſhews that her Nodes move from Eaſt towards the weſt, or contrary to the order of the Signs in the Ecliptic.

All theſe different modifications, by which the laws

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of the Moon's motions are regulated, is the caufe why fhe puts on feveral phafes and appearances, and always changing her figure; and with the multitude of her forms, fhe has frequently puzzled the minds and underftandings of thofe philofophers, who have moft contemplated her. Sometimes fhe increafes and grows bigger, then again fhe wanes and diminifhes, as it were in old age; fometimes fhe is bended into horns, and then again fhe appears like a half circle; at other times, fhe looks gibbous or hunch-backed, and immediately fhe affumes a full globular face; and afterwards, by degrees fhe difappears and lofes all her luftre; fometimes fhe keeps in the fouthern region of the Heavens, at other times fhe rifes high, and vifits the northern Hemifphere.

All thefe things were firft found out by Endymion, among the Greeks, who was the firft among them who watched her motions; therefore their poets have feigned the Moon to be in love with him, becaufe he fpent his time upon the mountains, chiefly on mount Latmos, in ftudying the nature of the Moon and Stars, fourteen hundred and forty five years before Chrift. But now fince the tables of all her motions are fo well adjufted, the ftudy of the theory of her motions are become practicable and eafy.

CHAP. XVII.

Of the Obfervations or Eclipfes of the Sun and Moon.

THERE is nothing in Aftronomy which fhews the great fagacity of the human underftanding and its deep penetration more than a clear explication of

the ſudden diſappearings of the Sun and Moon, that is of their Eclipſes, and the accurate predictions when they are to come to paſs, which the Aſtronomers can now foretell as to the time when they are to be, within a very few minutes. Tho' this be the niceſt and moſt ſubtle ſpeculation of the Aſtronomical ſcience, yet it is certain and undoubtable, than which nothing can be more ſublime, or worthy of our contemplation in ſcience. CHAP. XVII.

Obſervations teſtify, that ſeveral of the Planets, particularly Venus, Mercury and the Moon, receive their illumination, by the Sun, and all the Satellites of Jupiter and Saturn, and the Earth, are illuminated by the Sun, on that ſide which is towards him, and caſts a ſhadow towards that point of the Heavens which is oppoſite to the Sun. It is to be obſerved, that all dark and opaque bodies, when they are expoſed to the direct light of the Sun, caſt a ſhadow behind them, that is oppoſite to the line the Sun is in. Their ſhadow is nothing but the loſs or privation of light, in the ſpace oppoſite to the Sun, by reaſon the Sun's rays are intercepted by the opaque body.

Now, ſince the Earth is an opaque body, it muſt likewiſe caſt a ſhadow towards the ſpace oppoſite to the Sun, in which ſpace, if the Moon ſhould come, it muſt neceſſarily be darkened and loſe the light that it had before from the Sun. When the Moon is in an Eclipſe, the Sun appears Eclipſed to her, and total to all thoſe parts on which the ſhadow falls, and of as long continuance as they are in the ſhadow.

The Moon in like manner, upon the ſame account, muſt have a ſhadow of a conical figure oppoſite to the Sun; and if this ſhadow ſhould fall on the Earth, which can never happen, but when the Moon is in con-

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junction with the Sun, the inhabitants of the Earth, on whom the ſhadow will be, are involved in darkneſs, and the Sun to them will ſeem to be in an Eclipſe, ſo long as the ſhadow covers them. But, becauſe the Moon is much leſs than the Earth, its ſhadow can never cover the whole Earth, but only a ſmall part of it.

Hence, it is manifeſt, that there can be no Eclipſe of the Moon but in full Moon, when ſhe is oppoſite to the Sun, as the ſhadow always is. Nor can there be any Eclipſe of the Sun but in the new Moon, when ſhe is in conjunction with the Sun, for then only ſhe can caſt her ſhadow on the Earth. Since therefore, in every month there is one full Moon, and one new Moon, it may be aſked how it comes that the Sun and Moon do not ſuffer Eclipſes every month? And indeed, if the Moon did always move in the plane of the Ecliptic, ſince the centre of the Earth's ſhadow is always in the ſame plane, the Moon would then every full Moon paſs through the body of the ſhadow, and there would be a total Eclipſe of the Moon. So likewiſe, in every new Moon, if ſhe were not too far off us, ſhe would caſt her ſhadow on the Earth, and produce an Eclipſe of the Sun, in ſome one or other of the regions of the Earth. But the caſe is otherwiſe, for we have ſhewed that the plane of the Moon's orbit does not coincide with the plane of the Ecliptic, but that it cuts it in a line which paſſes through the centre of the Earth; and therefore, the Moon is never in the plane of the Ecliptic, but when ſhe is in this line, which is the interſection of the two planes, that is when ſhe enters the Nodes. And therefore, when it happens that the Moon at full ſhall likewiſe be in one of the Nodes, then the centre of the ſhadow will paſs

over the centre of the Moon, and then she will be in a total and central Eclipse. CHAP. XVII.

And there will always be central Eclipses when the centre of the Moon and the centre of shadow meet in the Nodes. Hence, the duration or time that an Eclipse can last, may be as long as the Moon is passing through an arch that is equal to four diameters of the Moon, that is about two degrees, which space the Moon generally moves through in the space of four hours. But, because of the largeness of the Earth's shadow in comparison of that of the Moon, there may be total Eclipses that are not centrical, where the Node does not coincide with the centre of the shadow; and the Node may likewise be at such a distance from the shadow, that there may be only a part of the Moon's body that can enter it, and then we shall have only a partial Eclipse of the Moon; and these partial Eclipses will be greater or less according as the distance of the shadow from the Node is less or greater. But when it happens that the Node in the time of full Moon, is further removed from the centre of the shadow than 12 degrees, the Moon then will have so much Latitude, or its distance from the Ecliptic will be so great, that it cannot be observed by the shadow.

As the shadow of the Earth cast upon the Moon produces an Eclipse of the Moon, so if the shadow of the Moon should fall on the Earth, it will cause an Eclipse of the Earth, at least on that part of the Earth on which the shadow falls. For the Moon being much less than the Earth, cannot with its shadow involve the whole disc of the Earth, but only a very small part of it; and so all Eclipses of the Earth will be partial and not total. And such eclipses will only produce a darkness upon those places where the shadow falls, and the in-

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habitants within this ſhadow will only ſee the Sun totally darkened, and therefore they will call them Eclipſes of the Sun. If the Earth and Sun were equally big, the Earth's ſhadow would be infinitely extended, and all of the ſame bulk, and the planet Mars, in either of its Nodes, and oppoſite to the Sun, would be eclipſed in the Earth's ſhadow. And were the Earth bigger than the Sun, its ſhadow would increaſe in bulk the further it extended, and eclipſe the planets Jupiter and Saturn, if theſe ſuperior planets be dark opaque bodies like Venus and Mercury. But it is certain, that the Satellites of Jupiter and Saturn are opaque bodies, and yet they are never obſerved to be Eclipſed by the Earth's ſhadow. And if the planet Mars ſhines only by the borrowed light of the Sun, he never was ſeen to be eclipſed by the ſhadow of the Earth, for any thing yet known. Therefore, the Earth's ſhadow muſt be of a conical figure, and end in a point, before it extend to the Satellites of Jupiter and Saturn at fartheſt; becauſe none of theſe Satellites has ever been obſerved to be involved in the ſhadow of the Earth, which ſhews that the Earth is leſs than the Sun. If the Sun and Moon were equally big, the Moon's ſhadow would go out to the Earth with an equal breadth, and cover a portion of the Earth's ſurface equal to the breadth of its diameter, even if it fell directly againſt the Earth's centre, as ſeen from the Moon, and much more if it fell obliquely on the Earth. But the Moon's ſhadow, even when ſhe is in the Perigee, and the Sun in the Apogee, does not exceed 150 miles broad at the Earth, unleſs when it falls very obliquely on the Earth, in a total Eclipſe of the Sun. In annular Eclipſes, when the Moon is in the Apogee and the Sun in the Perigee, the Moon's real

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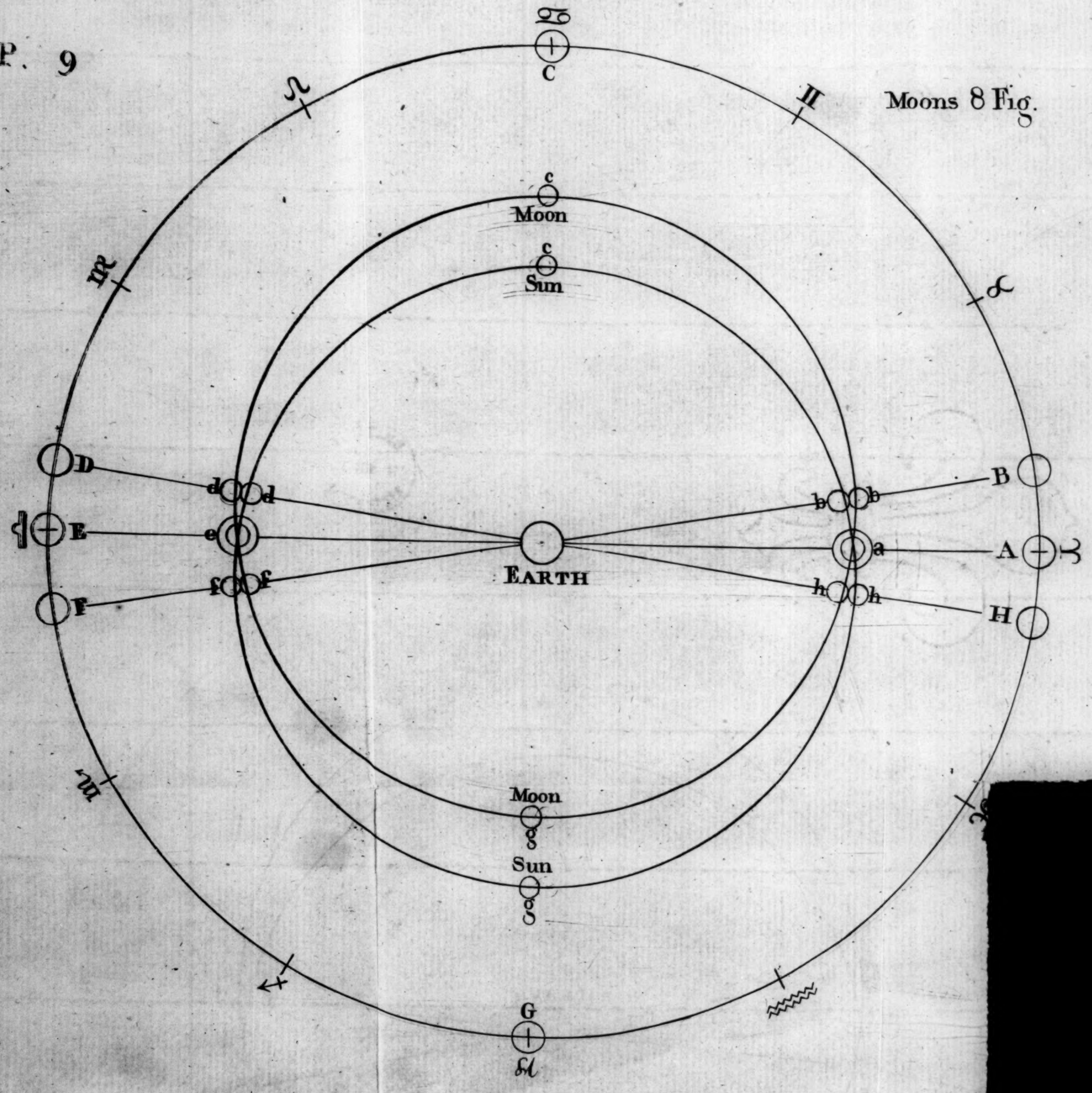
Moons 8 Fig.



ſhadow ends in a point at ſome diſtance from the Earth. The Moon's ſmall diſtance from the Earth, and the ſhortneſs of her ſhadow proves her to be leſs than the Sun: and the Earth's ſhadow is large enough to cover the Moon, if her diameter were three times as large as it is; which we find evident, from her long continuance in the ſhadow when ſhe goes through its centre. Hence, it is plain, that the Earth is much bigger than the Moon; and as the Sun and Moon are once in oppoſition and once in conjunction every month, whence we may imagine that theſe two luminaries ſhould be eclipſed every month. But there are few Eclipſes in reſpect of the number of new and full Moons; the reaſon of which, we ſhall now explain.

If the Moon's Orbit were coincident with the plane of the Ecliptic, in which the Sun always moves, the Moon's ſhadow would fall upon the Earth at every change, and eclipſe the Sun to ſome parts of the Earth. In like manner, the Moon would go through the middle of the Earth's ſhadow, and be eclipſed at every full; but with this difference, that ſhe would be totally darkened for above an hour and a half; whereas the Sun never was above 4 minutes totally eclipſed by the interpoſition of the Moon. But one half of the Moon's Orbit is elevated $5\frac{1}{3}$ degrees above the Ecliptic, and the other half as much depreſſed below it; conſequently, the Moon's Orbit interſects the Ecliptic in two oppoſite points, called the Moon's Nodes, as has been already taken notice of. When theſe points are in a right line with the centre of the Sun, at new and full Moon, the Sun, Moon and Earth, are all in a right line. And if the Moon be then new, her ſhadow falls upon the Earth; if full,

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the Earth's ſhadow falls upon her. When the Sun and Moon are more than 17 degrees from either of the Nodes, at the time of conjunction, (as taken at a mean rate between the Apogeal and Perigeal Eclipſes) the Moon is then generally too high or too low in her Orbit, to caſt any part of her ſhadow upon the Earth. And when the Sun is more than 12 degrees from either of the Nodes, at the time of full Moon, the Moon is generally too high or too low in her Orbit, to go through any part of the Earth's ſhadow. In both theſe caſes there will be no Eclipſe. But when the Moon is leſs than 17 degrees from either of the Nodes, at the time of conjunction, her ſhadow or penumbra falls more or leſs upon the Earth, as ſhe is more or leſs within this limit. And when ſhe is leſs than 12 degrees from either Node, at the time of oppoſition, as taken near a mean rate, ſhe goes thro' a greater or leſs portion of the Earth's ſhadow, as ſhe is more or leſs within this limit. Her Orbit contains 360 degrees, of which 17 is the limit of Solar Eclipſes on either ſide of the Nodes; and 12 degrees, the limit of Lunar Eclipſes, are but ſmall portions. And as the Sun commonly paſſes by the Nodes but twice in a year, it is no wonder that we have ſo many new and full Moons without Eclipſes.

Plate 9. The Moon's 8th Fig.

To illuſtrate this, as in figure 8, Let ACEG on the outmoſt circle be the Ecliptic, *aceg* a circle lying in the ſame plane with the Ecliptic, and *aceg* the Moon's Orbit, and the Earth in the centre. One half of the Moon's Orbit, as *ace*, is always above the Ecliptic, and the other half *ega* below it; the points *a* and *e* where the Moon's Orbit interſects the circle *aceg*, which lies even with the Ecliptic, are the Moon's Nodes; and a right line as AE drawn from the one

to the other, through the Earth's centre, is called the line of Nodes. And according to the form of this diagram, let the Nodes be ſuppoſed to be in Aries and Libra.

If the Moon moved round the Earth in the Orbit *aceg*, which is coincident with the plane of the Ecliptic, her ſhadow would fall upon the Earth every time ſhe is in conjunction with the Sun, and at every oppoſition ſhe would go through the Earth's ſhadow; were this the caſe, the Sun would be Eclipſed at every change, and the Moon at every full, as already mentioned; but this is not the caſe, as is here to be ſhown.

Let us then ſuppoſe the Sun and Moon to be in conjunction, exactly in the Node, when the line of Nodes is in Aries and Libra, viz. in Aries aſcending, and Libra deſcending. The Sun at A ♈ in the Zodiac, is totally Eclipſed by the Moon at *a* as ſeen from the Earth in the centre, and the body of the Moon appears to cover the diſc of the Sun at *a* in the interſection of the Moon's Orbit with the Ecliptic. In this caſe, when the Sun and Moon are in conjunction in the Node, if the Moon be then in the Perigee and the Sun in the Apogee, the Sun may then be Eclipſed totally for the ſpace of four minutes. But if the Moon ſhould then be in the Apogee, and the Sun in the Perigee, the diſc of the Sun would appear like a luminous ring about the body of the Moon, as we ſaw was the caſe, in the Eclipſe of the Sun in February 1737, when theſe two luminaries were then in ſuch a ſituation. And when the line of Nodes paſs through the firſt degree of Aries and Libra, if the Moon ſhould then be in oppoſition to the Sun in the Node, the Sun as at A ♈ and the Moon at *e* in the other Node, the ſhadow of the Earth would fall upon the Moon, and

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ſhe would be totally darkened for near the ſpace of an hour and a half, more or leſs according to her diſtance from the Apogee.

When the line of Nodes is in the ſituation here repreſented, viz. in the firſt degree of Aries and Libra, if the conjunction of the Sun and Moon be then, when the Sun is in the 10th degree of Aries, in the aſcending Node, as at B, there will be a partial Eclipſe upon the upper edge of the Sun, and the Moon will be ſeen to paſs over the upper part of the Sun's diſc, as at *bb* in the concave ſurface of the Heavens. But if the Sun ſhould be more than 18 degrees from the Node at the time of conjunction, the Moon would have too much Latitude, and paſs by the body of the Sun without any Eclipſe at all.

Plate 9. The Moon's 8th Fig.

And alſo in this ſituation of the Nodes, if the conjunction ſhould happen when the Sun is in the firſt degree of Cancer, as at ♋, the Moon in the Zodiac would then have $5\frac{1}{3}$ degrees of Latitude, and paſs by above the Sun at *cc* being 90 degrees diſtant from the Nodes, and the higheſt part of her Orbit; and both Luminaries are as far as poſſible from the limits of Eclipſes.

When the Sun is in the 20th degree of Virgo at D, and 10 degrees from the deſcending Node in Libra, at the time of the new Moon, and the Nodes in the ſituation aforeſaid, then part of the Moon's body will make a dint upon the upper edge of the Moon's diſc as ſhe paſſes by, and the Eclipſe will appear as at *dd*. And when the Sun is at E in the deſcending Node in the firſt degree of Libra, at the time of New Moon, the appearance is much the ſame as when the conjunction happens in the aſcending Node in the firſt degree of Aries; only with this difference, that the

Moon's body enters upon the Sun's disc a little above his diameter, and goes off a little below it in Libra. But in Aries, the Moon enters upon the Sun a little below his diameter, and goes off a little above it, if both Eclipses are viewed in the Meridian. CHAP. XVII.

When the Sun is in the 10th degree of Libra, and 10 degrees past the descending Node at the time of new Moon, part of the Moon's body will touch the Sun's disc upon the lower edge thereof, and if viewed in the Meridian will incline downwards as she passes over, and will be seen as at *ff* in the Ecliptic. And when the Sun is in the first degree of Capricorn at G, and the Nodes in this position, the Moon at her change in passing by the Sun is $5\frac{1}{3}$ degrees above the Ecliptic, and being 90 degrees from the Nodes, both the Luminaries are as far as possible from the limits of Eclipses, and pass by one another as at *gg*.

And if the Sun be in the 20th degree of Pisces at ♓, and 10 degrees from the ascending Node in Aries, he is then within the limits of Eclipses. And if the Moon be then in conjunction, she will then cover part of the Sun's disc as she passes by, and the Sun and Moon will be seen as at *hh* in the Ecliptic, and the Moon will cover the under edge of the Sun's disc. If the descending Node were in Aries, and the ascending Node in Libra, the body of the Moon would enter upon and pass over the Sun's disc the reverse way from this, that is, in place of her entering upon the Sun's disc, and ascending upwards in time of Eclipses, she would enter the disc of the Sun and descend downwards. Although all these different Eclipses, and situations of the Sun and Moon here mentioned, cannot happen successively when the

CHAP. XVII. Nodes are in this ſituation, yet one or more of them will.

If the line of the Nodes were immoveable in the Ecliptic, there would be juſt half-a-year between the conjunctions of the Sun and Nodes. But it is found, by obſervation, that the line of the Nodes does conſtantly change its place, and ſhift its ſituation, from eaſt to weſt, contrary to the order of the Signs, $19\frac{1}{3}$ degrees every year. Therefore the conjunctions, or oppoſitions of the Sun and Moon in the Nodes, is 19 days ſooner every year, than in the year before; conſequently, from the time that the Sun is in the aſcending Node at A, it is only 173 days (not half-a-year) till he be in the deſcending Node at E. Therefore, in whatever time of the year we have Eclipſes of the Luminaries about either Node, we may be ſure that in 173 days afterward, we ſhall have Eclipſes about the other Node. At this rate, the Nodes ſhift through all the ſigns and degrees of the Ecliptic in 18 years and 225 days, in which time there would always be a regular period of Eclipſes, if any compleat number of lunations were finiſhed without a fraction. But this never happens; for if both the Sun and Moon ſhould ſtart from a line of conjunction with either of the Nodes in any point of the Ecliptic, the Sun would perform 18 annual revolutions and 222 degrees over and above, and the Moon 230 lunations and 85 degrees of the 231, by the time the Node came round to the ſame point of the Ecliptic again; ſo that the Sun would then be 138 degrees from the Node, and the Moon 85 degrees from the Sun.

But in 223 mean lunations, after the Sun, Moon, and Nodes, have been once in a line of conjunction, they return ſo nearly to the ſame ſtate again, as that

the ſame Node, which was in conjunction with the Sun and Moon at the beginning of the firſt of theſe lunations, will be within 28 minutes 12 ſeconds of a degree, of a line of conjunction with the Sun and Moon again, when the laſt of theſe lunations is compleated. And therefore, in that time, there will be a regular period of Eclipſes, or a return of the ſame Eclipſe for many centuries. In this period, which is called the Chaldean Saros, and was firſt diſcovered by them, there is 18 Julian years 11 days 7 hours 43 minutes 20 ſeconds, when the laſt day of February in leap years is four times included. But when it is five times included, the period conſiſts only of 18 years 10 days 7 hours 43 minutes 20 ſeconds; conſequently, to the mean time of any Eclipſes, either of the Sun or Moon, you add 18 Julian years 11 days 7 hours 43 minutes 20 ſeconds, when the laſt day of February, in leap years, comes in four times, or a day leſs when it comes in five times, you will have the mean time of the return of the ſame Eclipſe very near for many ages. But the falling back of the line of conjunctions or oppoſitions of the Sun and Moon 28 minutes 12 ſeconds, with reſpect to the line of the Nodes in every period, will wear it out in proceſs of time.

In any year, the number of Eclipſes of both Luminaries, cannot be leſs than two, or more than ſeven: the moſt uſual number is four, and it is very ſeldom that there is more than ſix. For the Sun paſſes by both the Nodes once a year, unleſs he paſſes by one of them in the beginning of the year; and if he does, he will paſs by the ſame Node again a little before the year is finiſhed; becauſe as theſe points move $19\frac{1}{3}$ degrees backward every year, the Sun will come to

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either of them 173 days after the other, as we have before taken notice of. And when the Sun is within 17 degrees of either Node, at the time of new Moon, the Sun will be Eclipſed. At the ſubſequent oppoſition, the Moon will be Eclipſed in the other Node, and come round to the next conjunction again, before the former Node be 17 degrees paſt the Sun, and will therefore Eclipſe the Sun again. When three Eclipſes fall about either Node, the like number generally falls about the oppoſite one, as the Sun comes to it in 173 days afterwards, and ſix Lunations contain but four days more. Thus, there may be two Eclipſes of the Sun, and one of the Moon, about each of her Nodes. But when the Moon changes exactly in either of the Nodes, ſhe cannot be near enough the other Node at next full to be Eclipſed; but in ſix Lunar months afterwards, ſhe will change near the other Node; and in theſe caſes, there can be but two Eclipſes in a year, and they are both of the Sun.

CHAP. XVIII.

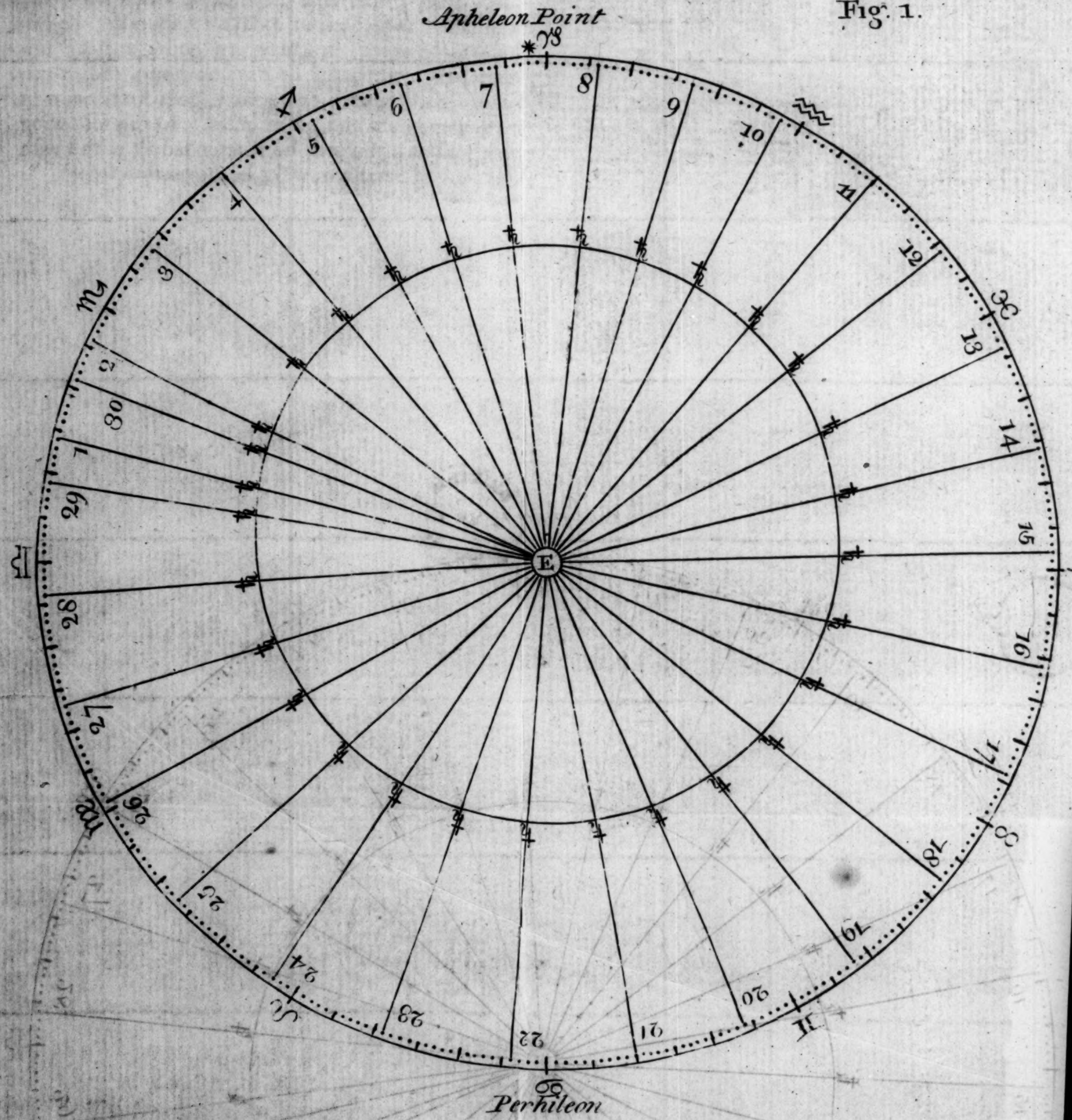
Shewing the Equated times of Saturn's moving through all the Signs of the Zodiac, and the time it requires to take between two oppoſitions of the Sun and Saturn.

SATURN is the moſt diſtant of all the Planets, and moves through all the Signs of the Zodiac in the ſpace of 29 years 167 days and 5 hours of our time. And the time between two oppoſitions of the Sun and Saturn, immediately following one another, computed according to their middle motions, is a year and 13 days.

PLATE X.

SATURNS

Fig. 1.



Saturn is ſurrounded by a thin broad Ring, as an artificial Globe is by a Horizon, and has five Satellites or ſmall Stars, all going round him on the outſide of his Ring. The firſt or neareſt Satellite to Saturn, goes round him in 1 day 21 hours and 19 minutes; the ſecond, in 2 days 17 hours and 40 minutes; the third, in 4 days 12 hours and 25 minutes; the fourth, in 15 days 22 hours and 41 minutes; and the fifth or outmoſt, goes round him in 79 days 7 hours and 48 minutes. In the following deſcriptions of Saturn, he is attended all round with this train of Satellites, when he moves through all the Signs of the Zodiac, in the ſpace of near 30 years, and alſo from one oppoſition to another. The Orbit of Saturn is $2\frac{1}{2}$ degrees inclined to the Ecliptic or Orbit of the Sun, and interſects it in the 21ſt degree of Cancer and of Capricorn. CHAP. XVIII.

As I have in the following ſcheme given Saturn's place in the Heavens very minutely, and his Tranſit over the Meridian may be found thereby within a very few minutes, which no Aſtronomer before has ever done. I have taken the various motions of Saturn and Jupiter from their periods, contained in the tables compoſed by Doctor Edmund Halley, and Monſieur De La Callie. The curious reader will ſee the quotations juſtly taken from theſe tables, which I have here mentioned, by looking into the Doctor's book of Tables themſelves.

We ſhall then here ſhew Saturn's paſſage through the Signs of the Zodiac, from the year 1658 to the year 1718, in which time Saturn made two compleat revolutions through all the Signs of the Zodiac, and 14 degrees of Libra more, as we have here inveſtigated them by regular copper-plate drawings, from the foreſaid Aſtronomical tables.

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We ſhall then here deſcribe and explain Saturn's firſt figure. In this figure, the twelve Signs of the Zodiac are marked on the outſide of the outmoſt circle, in their proper characters; and every Sign is divided into 30 degrees on this circle. The inmoſt circle ſhews Saturn's paſſages in the Heavens, and the manner of his appearance in the Signs, on which Saturn is marked with his proper character, and the Earth is placed in the centre at E, and Saturn's Aphelial point is in the 28 degree of Sagittarius, and the eccentricity of this Zodiac courſe, is very near as 43 is to 780, or about an 18th part.

Plate 10. Saturn's 1ſt Fig.

This firſt figure of Saturn, ſhews us one compleat revolution that he made through the Signs of the Zodiac, and 7 degrees more, viz. from the 24th day of March 1658, to the 31ſt of March 1688.

We deſcribe this periodical revolution in particular, by ſhewing in what degree of the ſeveral Signs of the Zodiac Saturn was in, through the whole of his courſe, in this period before us. On the foreſaid year 1658, and 24th day of March, Saturn was ſeen in the 14th degree of Libra, according as the Aſtronomical tables ſhew. And likewiſe, according to this figure, Saturn in his Orbit is ſeen from the Earth in the centre at E, to appear in the 14th degree of Libra, as marked on the outmoſt circle, as the Radius line drawn through the Planet's place, at the figure 1 doth ſhew. And on the 6th day of April, in the year 1659, according to the foreſaid tables, Saturn was ſeen in the 26th degree of Libra; and the Radius line, drawn thro' the Planet's place, doth ſhew the ſame, at figure 2d on the outmoſt circle. Again, on April 17th, and year 1660, Saturn was ſeen in the 8th degree of Scorpio, according to the tables, and the Radius

line, through the Planet's place, ſheweth the ſame at figure 3d. And on April 30th, in the year 1661, Saturn was ſeen in the 20th degree of Scorpio; and the 4th line, drawn through the Planet's place, ſheweth the ſame. On the 12th day of May 1662, Saturn was ſeen in the 2d degree of Sagittarius; and the 5th line, thro' the Planet's place, in this figure, ſheweth the ſame.

And on the 24th day of May 1663, Saturn was ſeen in the 13th degree of Sagittarius; and the 6th line, through the Planet's place, ſheweth the ſame on the outmoſt circle. Again, on the 4th day of June 1664, Saturn was ſeen in the 24th degree of Sagittarius; and the 7th line, through the Planet's place, ſheweth the ſame. On the 16th day of June 1665, Saturn was ſeen in the 6th degree of Capricorn; and the 8th line, through the Planet's place, ſheweth the ſame. And on the 28th day of June 1666, Saturn was ſeen in the 17th degree of Capricorn; and the 9th line, through the Planet's place, ſheweth the ſame. Alſo, on the 11th day of July 1667, Saturn was ſeen in the 28th degree of Capricorn; and the 10th line, through the Planet's place, ſheweth the ſame. On the 22d day of July 1668, Saturn was ſeen in the 10th degree of Aquarius; and the 11th line, through the Planet's place, ſheweth the ſame.

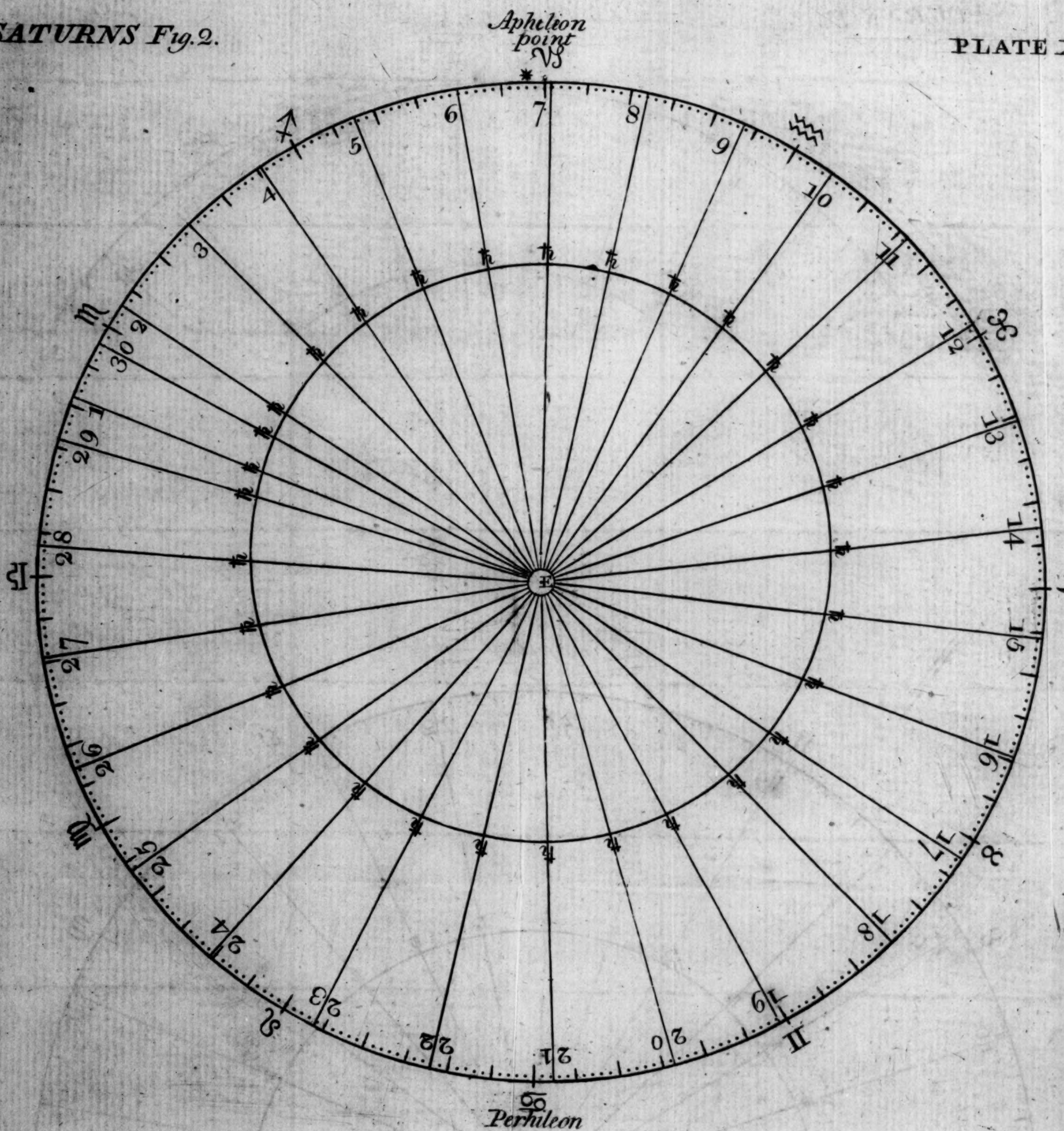
And the 3d day of Auguſt 1669, Saturn was ſeen in the 21ſt degree of Aquarius; and the 12th line, through the Planet's place, ſheweth the ſame. On the 16th day of Auguſt 1670, Saturn was ſeen in the 4th degree of Piſces; and the 13th line, through the Planet's place, ſheweth the ſame. On the 29th day of Auguſt 1671, Saturn was ſeen in the 16th degree of Piſces; and the 14th line, through the Planet's place, ſheweth the ſame. On the 10th day of Sep-

CHAP. XVIII. tember 1672, Saturn was ſeen in the 28th degree of Piſces; and the 15th line, through the Planet's place, ſheweth the ſame. On the 23d day of September 1673, Saturn was ſeen in the 11th degree of Aries; and the 16th line, through the Planet's place, ſheweth the ſame. On the 7th day of October 1674, Saturn was ſeen in the 24th degree of Aries; and the 17th line, through the Planet's place, ſheweth the ſame.

Likewiſe, on the 21ſt day of October 1675, Saturn was ſeen in the 8th degree of Taurus; and the 18th line, through the Planet's place, ſheweth the ſame. On the 3d day of November 1676, Saturn was ſeen in the 22d degree of Taurus; and the 19th line through the Planet's place, ſheweth the ſame. On the 17th day of November 1677, Saturn was ſeen in the 6th degree of Gemini; and the 20th line, through the Planet's place, ſheweth the ſame. On the 1ſt day of December 1678, Saturn was ſeen in the 20th degree of Gemini; and the 21ſt line, thro' the Planet's place, ſheweth the ſame. On the 15th day of December 1679, Saturn was ſeen in the 4th degree of Cancer; and the 22d line, through the Planet's place, ſheweth the ſame. On the 29th day of December 1680, Saturn was ſeen in the 19th degree of Cancer; and the 23d line, through the Planet's place, ſheweth the ſame.

Yet further, on the 12th day of January 1682, Saturn was ſeen in the 3d degree of Leo; and the 24th line, through the Planet's place, ſheweth the ſame. On the 26th day of January 1683, Saturn was ſeen in the 17th degree of Leo; and the 25th line, through the Planet's place, ſheweth the ſame. On the 8th day of February 1684, Saturn was ſeen in the 1ſt de-

SATURNS Fig. 2. PLATE XI.



gree of Virgo; and the 26th line, through the Planet's place, ſheweth the ſame. On the 21ſt day of February 1685, Saturn was ſeen in the 13th degree of Virgo; and the 27th line, through the Planet's place, ſheweth the ſame. On the 6th day of March 1686, Saturn was ſeen in the 26th degree of Virgo; and the 28th line, through the Planet's place, ſheweth the ſame. And on the 19th day of March 1687, Saturn was ſeen in the 9th degree of Libra; and the 29th line, through the Planet's place, ſheweth the ſame. And laſtly, here on this figure, on the 31ſt day of March 1688, Saturn was ſeen in the 21ſt degree of Libra; and the 30th line, through the Planet's place, ſheweth the ſame. CHAP. XVIII.

This firſt figure ſheweth the place of Saturn in the ſigns of the Zodiac, for 30 years and 7 days; in which his Heliocentric place is found to paſs through all the ſigns, and 7 degrees more, and contains 29 of his returns to the Perigee.

We ſhall here alſo exemplify and explain another of Saturn's periods, in his paſſing through the ſigns of the Zodiac, which is here reduced likewiſe as the former, under a Geometrical conſtruction, and repreſented by figure 2d here. This figure is to be underſtood by the explanation which was given of the former, they being exactly ſimilar. The ſigns of the Zodiac, and the degrees of the ſigns, are marked on the outmoſt circle; and Saturn's place and character is marked on the inmoſt circle; and the Earth is placed in the centre at E. Plate 11. Saturn's 2d Fig.

We here begin Saturn's paſſage in the ſigns of the Zodiac, according to the Aſtronomical tables of this Planet; and alſo in this diagram, where it ended in the laſt, to wit, in the 21ſt degree of Libra, as ſeen

CHAP. XVIII. at figure 1st, which the Radius line from the Earth in the centre at E pointeth to, and in which Saturn was seen on the foresaid 31st day of March, in the year 1688, as the table of this Planet for that day doth testify. And on the 12th day of April 1689, Saturn was seen in the 3d degree of Scorpio; and the 2d line, through the Planet's place, sheweth the same. On the 25th day of April 1690, Saturn was seen in the 15th degree of Scorpio, and the 3d line, through the Planet's place, sheweth the same. On the 7th day of May 1691, Saturn was seen in the 26th degree of Scorpio; and the 4th line, through the Planet's place, sheweth the same. On the 18th day of May 1692, Saturn was seen in the 8th degree of Sagittarius; and the 5th line, through the Planet's place, sheweth the same.

And likewise, on the 30th day of May 1693, Saturn was seen in the 19th degree of Sagittarius; and the 6th line, through the Planet's place, sheweth the same. On the 11th day of June 1694, Saturn was seen in the 1st degree of Capricorn; and the 7th line, through the Planet's place, sheweth the same. On the 23d day of June 1695, Saturn was seen in the 12th degree of Capricorn; and the 8th line, through the Planet's place, sheweth the same. On the 5th day of July 1696, Saturn was seen in the 23d degree of Capricorn; and the 9th line, through the Planet's place, sheweth the same. On the 17th day of July 1697, Saturn was seen in the 5th degree of Aquarius; and the 10th line, through the Planet's place, sheweth the same. On the 29th day of July 1698, Saturn was seen in the 16th degree of Aquarius; and the 11th line, through the Planet's place, sheweth the same.

As alſo, on the 11th day of Auguſt 1699, Saturn was ſeen in the 28th degree of Aquarius; and the 12th line, through the Planet's place, ſheweth the ſame. On the 23d day of Auguſt 1700, Saturn was ſeen in the 10th degree of Piſces; and the 13th line, through the Planet's place, ſheweth the ſame. On the 5th day of September 1701, Saturn was in the 23d degree of Piſces; and the 14th line, through the Planet's place, ſheweth the ſame. On the 18th day of September 1702, Saturn was ſeen in the 6th degree of Aries; and the 15th line, through the Planet's place, ſheweth the ſame. On the 1ſt day of October 1703, Saturn was in the 19th degree of Aries; and the 16th line, through the Planet's place, ſheweth the ſame. And on the 14th day of October 1704, Saturn was ſeen in the 2d degree of Taurus; and the 17th line, through the Planet's place, ſheweth the ſame. CHAP. XVIII.

And further, on the 28th day of October 1705, Saturn was in the 16th degree of Taurus; and the 18th line, through the Planet's place, ſheweth the ſame. On the 11th day of November 1706, Saturn was ſeen in the 1ſt degree of Gemini; and the 19th line, through the Planet's place, ſheweth the ſame. On the 25th day of November 1707, Saturn was in the 14th degree of Gemini; and the 20th line, thro' the Planet's place, ſheweth the ſame. On the 8th day of December 1708, Saturn was in the 28th degree of Gemini; and the 21ſt line, through the Planet's place, ſheweth the ſame. On the 22d day of December 1709, Saturn was in the 12th degree of Cancer; and the 22d line, through the Planet's place, ſheweth the ſame. And on the 6th day of January 1711, Saturn was in the 27th degree of Cancer; and

CHAP. XVIII. the 23d line, through the Planet's place, ſheweth the ſame. And on the 20th day of January 1712, Saturn was ſeen in the 10th degree of Leo; and the 24th line, through the Planet's place, ſheweth the ſame.

Yet again, on the 1ſt day of February 1713, Saturn was in the 24th degree of Leo, and the 25th line, thro' the Planet's place, ſheweth the ſame. On the 15th day of February 1714, Saturn was in the 8th degree of Virgo, and the 26th line, thro' the Planet's place, ſheweth the ſame. On the 28th day of February 1715, Saturn was in the 21ſt degree of Virgo; and the 27th line, through the Planet's place, ſheweth the ſame. On the 12th day of March 1716, Saturn was in the 4th degree of Libra; and the 28th line, thro' the Planet's place, ſheweth the ſame. On the 25th day of March 1717, Saturn was ſeen in the 16th degree of Libra; and the 29th line, through the Planet's place, ſheweth the ſame. And laſtly, here on this figure, on the 7th day of April 1718, Saturn was ſeen in the 28th degree of Libra; and the 30th line, thro' the Planet's place, ſheweth the ſame.

This figure ſheweth the place of Saturn, in the Signs of the Zodiac, for the ſpace of 30 years and 7 days, according to the Aſtronomical tables. And he is thereby found to paſs through all the Signs, and 7 degrees more, and contains 29 of his returns to the Perigee. We alſo ſee from theſe two foregoing figures, that every one of Saturn's returns to the Perigee, is equally divided and diſtant from one another, in this Orbitual courſe of the Planet, as it is divided on this circle, and according to the mean motion of this Planet.

Having ſhewed two of Saturn's revolutions in his paſſing twice thro' all the Signs of the Zodiac, and 14

degrees of Libra more, by the two foregoing figures which he compleated and accomplished, between March 24th 1658, and April 7th 1718, being the space of 60 years and 14 days, in which time this Planet made 58 returns to his Perigee.

Plate 12. Saturn's 3d Fig.

We come next to describe from Saturn's 3d figure, his appearances in the Signs from one Perigee to another, or one opposition to another, which is here calculated from Monsieur De La Callie's Astronomical tables. This figure is constructed to represent Saturn's passage and appearance in the Zodiac, from his opposition July 29th 1756, to his next opposition August 11th 1757, Saturn being then in Aquarius. And it is here to be considered, that Saturn takes 378 days, or a year and 13 days, between one Perigee or opposition to another, according to the middle motion of the Planet; and when this time is divided by 12 according to the Radius lines in the figure, it is 31 days and one half. And here, before we describe the movement of the Planet, we shall shew the manner of the figure.

In this figure, the Earth is placed in the centre at E; the next circle is the Orbit of the Sun, on which the Sun is marked thus ☉; the second circle is the Orbit or situation of Saturn, drawn near about its proportional distance from the Earth, and Orbit of the Sun. In which Orbitual situation of Saturn, the Sun is placed in the centre, tho' both of them are seen to move diurnally around the Earth; and the outmost circle shows the movement of Aquarius about the Earth and Sun, for the space of 1 year and 13 days. This 13 odd days is carried on by the circular line on the outside at O: this outmost circle with the addition of said circular line for the 13 odd days, is divided into

CHAP. XVIII. twelve equal parts, to correſpond with Saturn's period, in which time he returns from one oppoſition to another, as hath been ſaid. The Planets time and circle being alſo divided exactly into twelve.

We ſhall, in the deſcription, begin and go on according to the Aſtronomical Tables of this Planet for this period. On the foreſaid 29th day of July 1756, Saturn was in oppoſition or Perigee, and ſeen in the 7th degree of Aquarius. And we here ſee by this figure, that Saturn as marked at A, with his proper character, is ſeen from the Earth at E, to appear in the 7th degree of Aquarius, marked thus ♒ at B on the outmoſt circle; and the Radius line, through the Planet's place, ſheweth the ſame.

And on the 29th day of Auguſt thereafter, or ſpace of 31 days and one half, Saturn was ſeen between the 4th and 5th degree of Aquarius at C; and the Radius line, through the Planet's place, ſheweth the ſame at B. On the 30th day of the next September, or further ſpace of 31 days and one half, Saturn was ſeen between the 3d and 4th degree of Aquarius at D; and the ſtraight line, thro' the Planet's place at C, ſheweth the ſame. And on the 1ſt day of the then next November, Saturn was ſeen in the 4th degree of Aquarius at E; and the ſtraight line, through the Planet's place, ſheweth the ſame at D. On the 2d day of December then next, Saturn was ſeen in the 6th degree of Aquarius at F; and the ſtraight line, thro' the Planet's place, ſheweth the ſame at E. On the 2d day of January 1757, Saturn was ſeen in the 9th degree of Aquarius at G; and the ſtraight line, thro' the Planet's place at F, ſheweth the ſame.

And on the 3d day of February then next, Saturn being in conjunction, he was ſeen in the 13th degree

PLATE XII.

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Fig. 3.

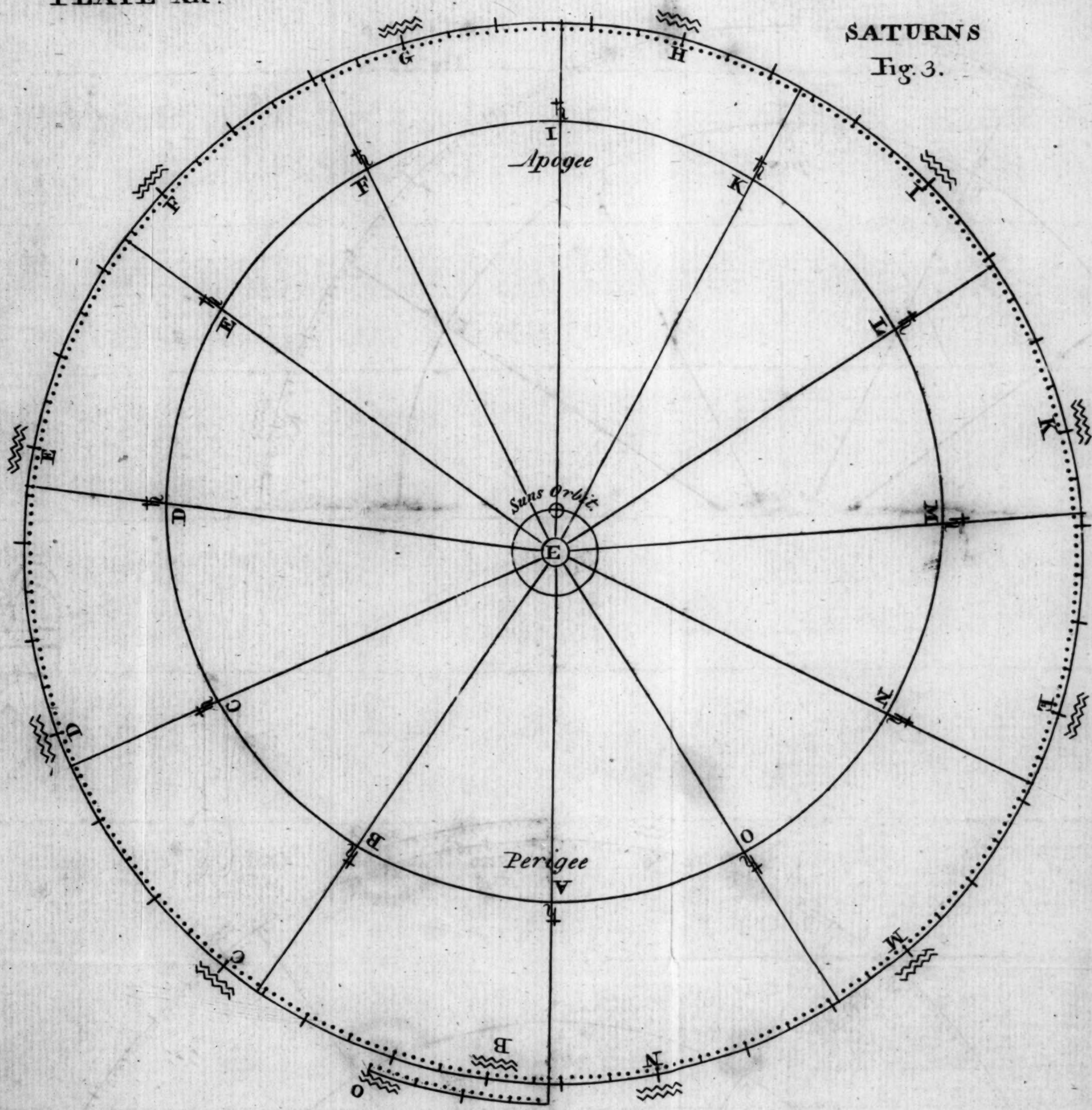
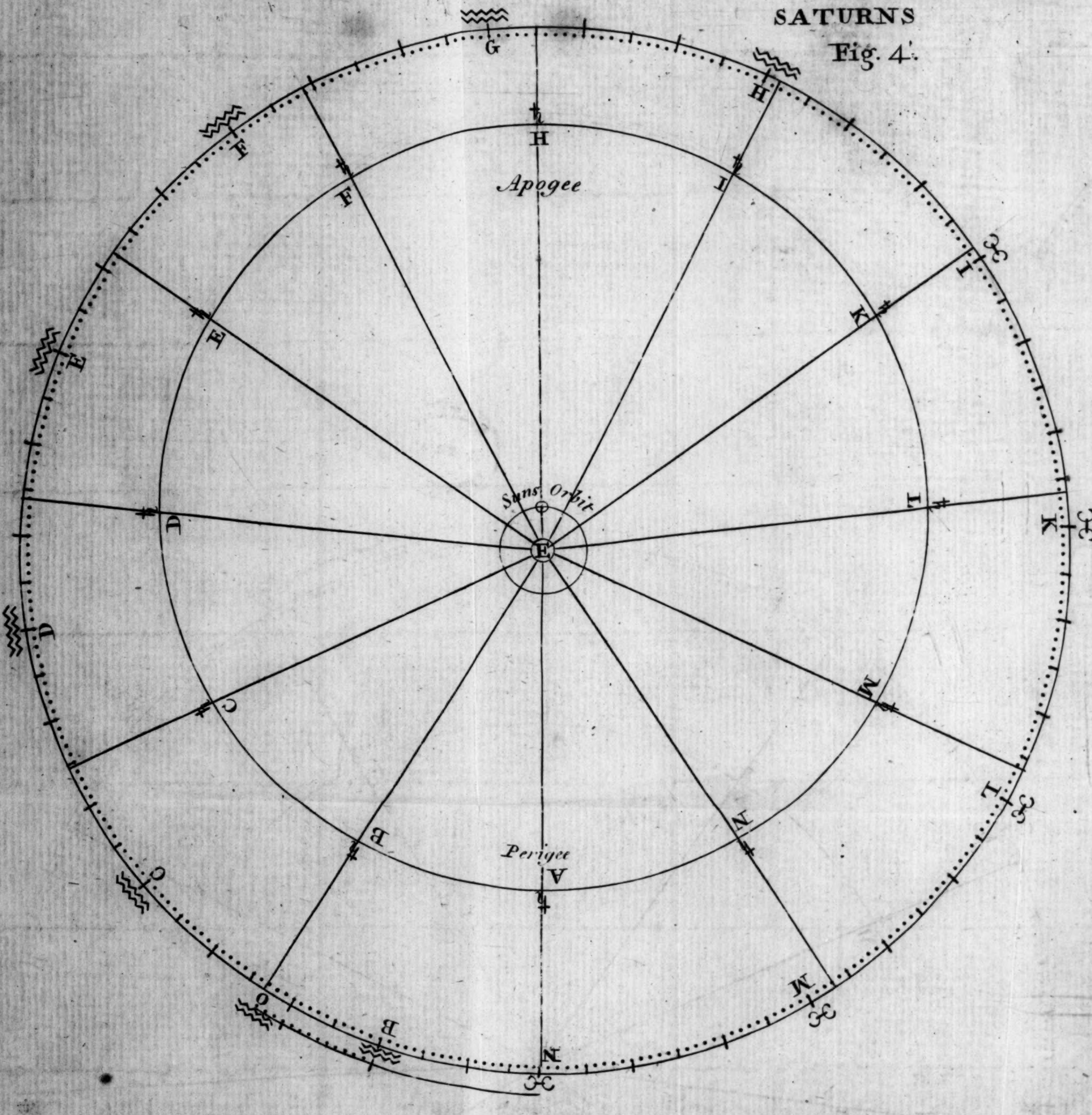


PLATE XIII.

SATURNS

Fig. 4.



of Aquarius at H; and the ſtraight line, through the Planet's place, ſheweth the ſame at I. On the 6th day of March then next, Saturn was ſeen between the 16th and 17th degrees of Aquarius at I; and the next line, through the Planet's place at K, ſheweth the ſame. On the 6th day of April alſo next, Saturn was ſeen In the 19th degree of Aquarius at K; and the ſtraight line, through the Planet's place at L, ſheweth the ſame. On the 8th day of May, Saturn was between the 21ſt and 22d degrees of Aquarius at L; and the next line, through the Planet's place at M, ſheweth the ſame. On the 8th day of June, Saturn was ſeen in the 22d degree of Aquarius at M; and the next line, through the Planet's place at N, ſheweth the ſame. And on the 10th day of July next, Saturn was ſeen in the 21ſt degree of Aquarius at N; and the ſtraight line, through the Planet's place at O, ſheweth the ſame.

And yet again, on the 11th day of Auguſt then next, Saturn was in oppoſition, and between the 18th and 19th degree of Aquarius; and the ſtraight line, through the Planet's place at A, is directed between the 18th and 19th degrees of Aquarius, as is marked on the circular line, on the outſide at O. This ſhort circular line, repreſents that the Conſtellation Aquarius, has gained and compleated one circulation more than the Sun, and near 13 days over, in the ſpace of a year and 13 days. In which time, Saturn proceeds from one oppoſition to another, which is to be noted, according to the mean motion of this Planet.

We ſhall next, by Saturn's 4th figure, deſcribe his appearance in the Signs of the Zodiac, from one Perigee or oppoſition to another; viz. from Auguſt 11th 1757, to Auguſt 23d 1758, Saturn being then

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Saturn's 4th Fig.

partly in Aquarius, and partly in Pisces. This figure is constructed just like the other last described; the Earth is placed in the centre at E; the next circle is the Orbit of the Sun, on which the Sun is marked thus ☉; the second circle, is the Orbit or station of Saturn, in which Orbitual situation of Saturn, the Sun is placed in the centre, and both of them appear to move diurnally about the Earth; and the outmost circle shews the movement of Aquarius and Pisces about the Earth and Sun for 1 year and 13 days; this odd 13 days, being carried on and represented by the circular line on the outside at O; the outmost circle, with the addition of the said circular line for the 13 odd days, being divided into 12 equal parts, in correspondence with Saturn's period and circle, which is divided exactly into twelve also.

We shall begin this period of Saturn, where we ended in the last; to wit, on the 11th day of August 1757, he being then in opposition or Perigee, and between the 18th and 19th degree of Aquarius, and the Radius line, through the Planet's place at A, pointeth to between the 18th and 19th degree of Aquarius, as marked at B, on the outmost circle. And on the 11th day of the then next September, or intervening space of 31 days and one half, Saturn was seen in the 16th degree and 32 minutes of Aquarius at C; and the next straight line, through the Planet's place at B, sheweth the same. On the 13th day of October then next, Saturn was seen between the 15th and 16th degrees of Aquarius at D; and the straight line, through the Planet's place at C, sheweth the same. On the 13th day of November then next, Saturn was seen in the 16th degree of Aquarius at E; and the straight line, through the Planet's place, sheweth the same as at D.

Further, on the 15th day of December then next, Saturn was ſeen in the 18th degree of Aquarius at F, and the ſtraight line, through the Planet's place at E, ſheweth the ſame. On the 15th day of January 1758, Saturn was ſeen in the 21ſt degree of Aquarius at G, and the ſtraight line, through the Planet's place at F, ſheweth the ſame.

And alſo, on the 16th day of February, Saturn was ſeen in the 25th degree of Aquarius at H, being then in conjunction; and the ſtraight line, through the Planet's place at H, ſheweth the ſame.

On the 19th day of March, Saturn was ſeen between the 28th and 29th degrees of Aquarius at I; and the ſtraight line, through the Planet's place at I, ſheweth the ſame. On the 20th day of April, Saturn was ſeen between the 1ſt and 2d degree of Piſces at l; and the ſtraight line, through the Planet's place at K, ſheweth the ſame.

In our deſcription at this place of the figure, the reader muſt obſerve, that Piſces in circulating about after Aquarius, is 30 degrees diſtant from Aquarius; and ſo Saturn from being ſeen in the 29th degree of Aquarius, is here ſeen in the 1ſt degree of Piſces, and ſo on afterwards through that Sign. And on the 21ſt day of May then next, Saturn was ſeen between the 3d and 4th degrees of Piſces at K, and the ſtraight line, through the Planet's place at L, ſheweth the ſame. On the 22d day of June, Saturn was ſeen in the 4th degree of Piſces at L, and the ſtraight line, through the Planet's place at M, ſheweth the ſame. On the 23d day of July, Saturn was ſeen in the 2d degree and 46 minutes of Piſces at M, and the ſtraight line, through the Planet's place at N, ſheweth the ſame. And laſtly here, on the 23d day of Auguſt then next,

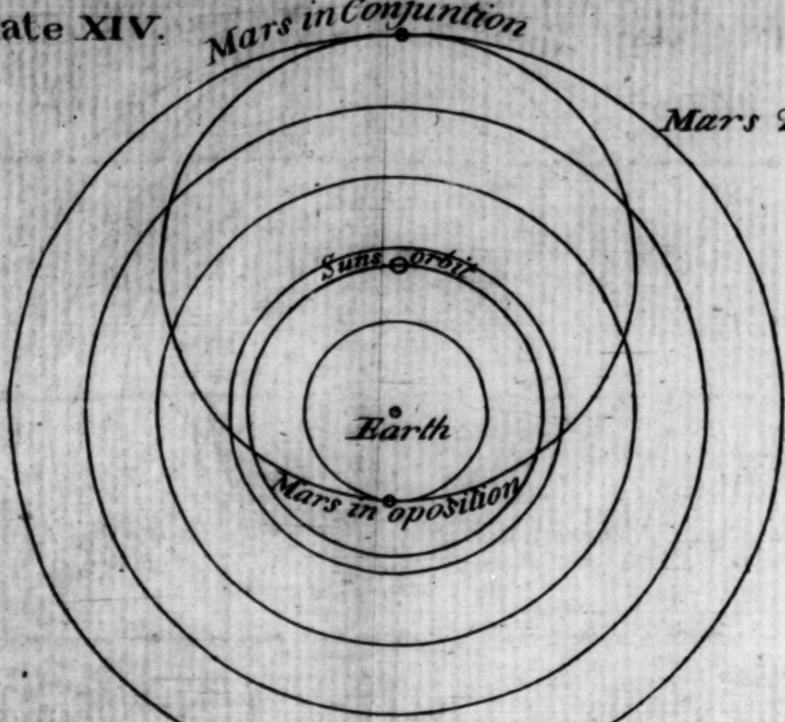
CHAP. XVIII. Saturn was ſeen in the 38th minute of the firſt degree of Piſces at N; and the next line, through the Planet's place at A, ſheweth the ſame.

Saturn being now again returned to the oppoſition and Perigee, and to come to an end with the deſcription of this figure, we ſee that Piſces at N, and Aquarius at O, has moved further about in the time of this period than Saturn; for Aquarius at O, is 13 degrees further advanced than Aquarius at B is; and when the eccentricity of Saturn's Orbitual courſe is taken together, as in this and the former diagram, it ſhews the manner how that Saturn is ſeen ſometimes to move backwards, and at other times to move forwards in the Signs of the Zodiac, which may be obſerved by the reader, upon an exact inſpection of theſe two laſt figures.

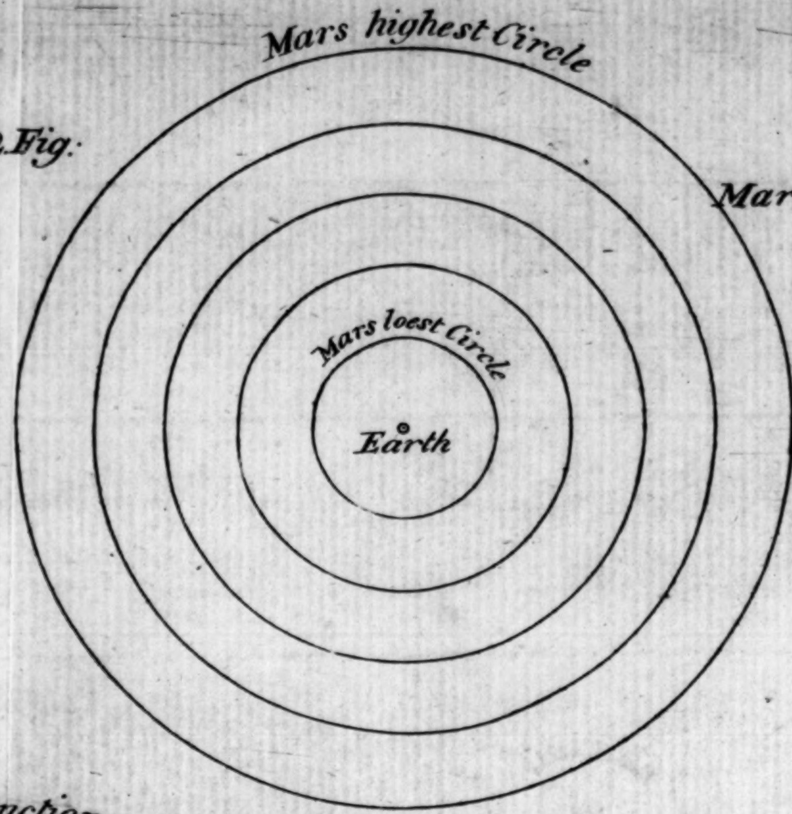
And figures of this conſtruction may be made, for every one of Saturn's periods, in returning to the oppoſition or Perigee, which will ſhew Saturn's place in the Signs of the Zodiac, within half a degree. But the Aſtronomer that is inclined to draw figures of Saturn's Apogeon periods, muſt firſt make out one after the conſtruction of figures, 1 and 2, that ſhews the manner how Saturn proceeds through the Signs of the Zodiac, in the ſpace of 30 years, ſo as to fix the Aphelion and Perihelion points exactly, and then he will the more nicely know the preciſe times of Saturn's returns to the Perigee or oppoſition, and the Planet's Equation. And theſe examples that are here given, will ſhew the manner of their conſtruction.

Having here ſhewed two of Saturn's revolutions, through all the Signs of the Zodiac, according to Dr. Halley's Tables; and alſo his appearance in the

Plate XIV.

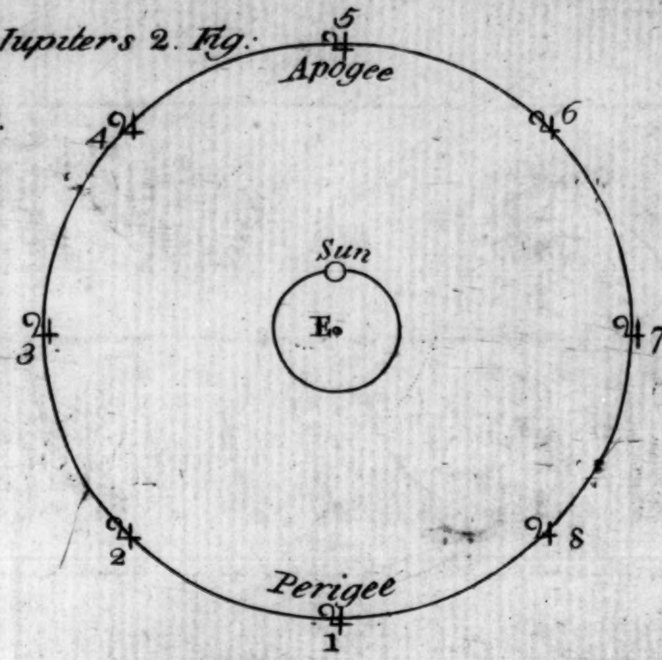


Mars 2 Fig.

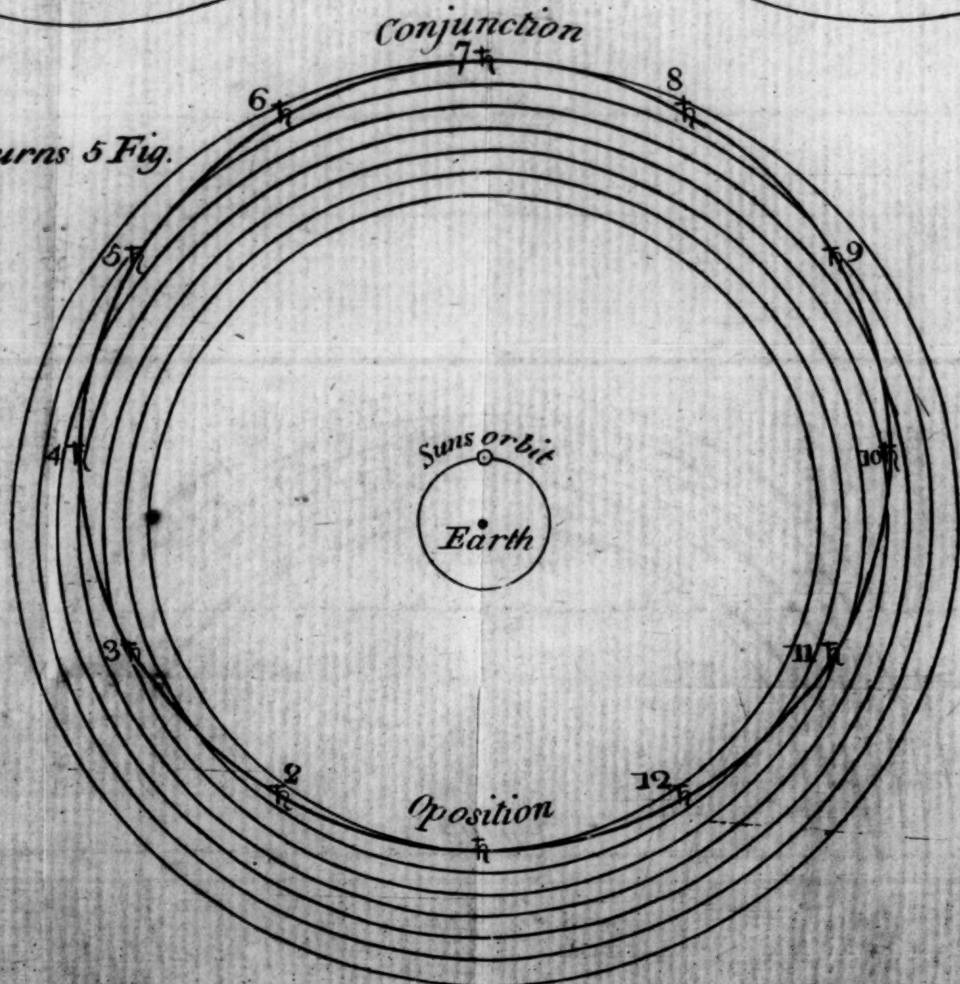


Mars 1 Fig.

Jupiters 2. Fig.



Saturns 5 Fig.



Jupiters 1. Fig.

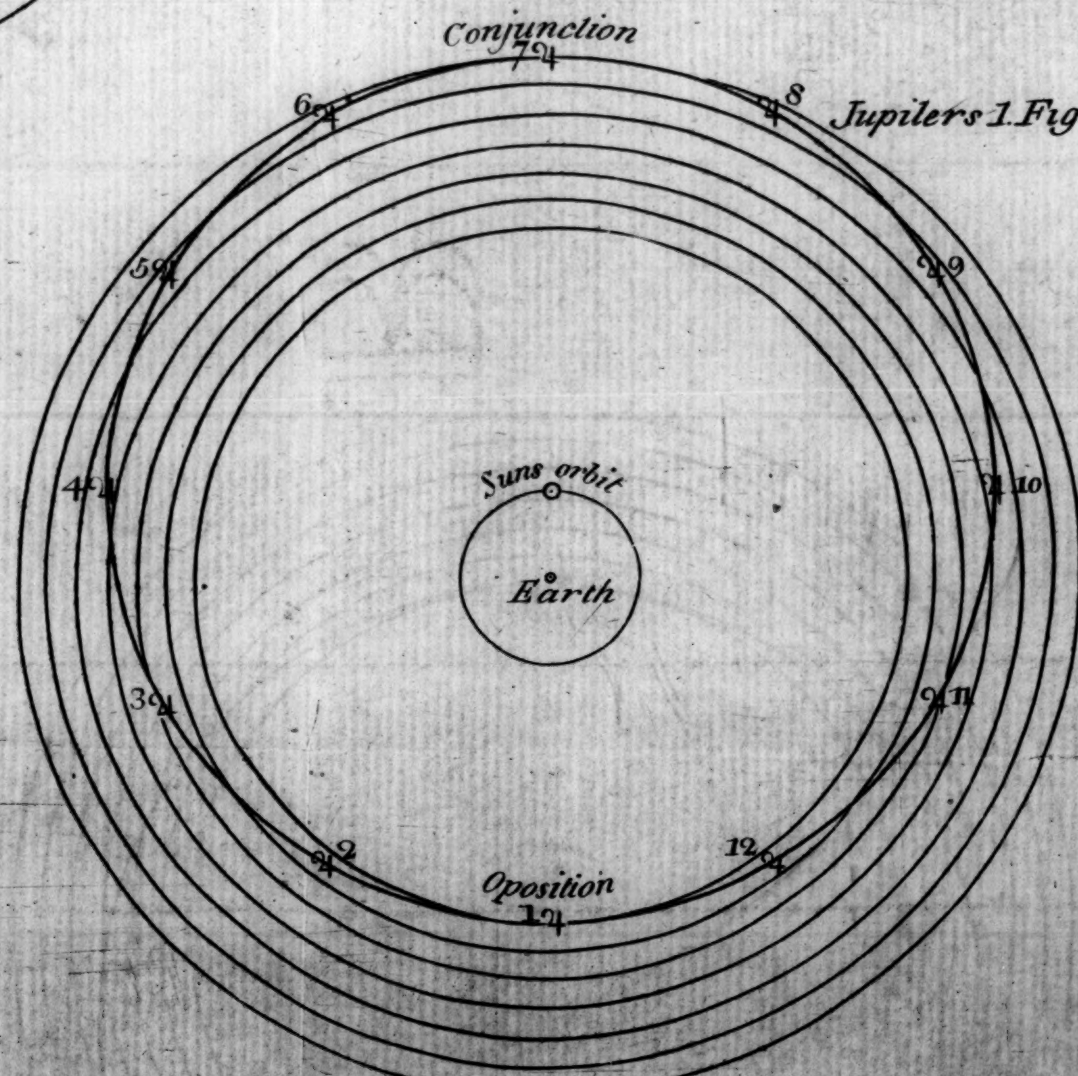


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Plate 14. Saturn's 5th Fig.

Signs, from one Perigeon or oppoſition to another, as calculated from De La Callie's Tables. We come next to ſhew, from figure 5, the order of Saturn's diurnal motion around the Earth, and the manner of his movement about the Sun, from one Perigeon or oppoſition to another. In this figure, the Earth is placed in the centre at E; and the next circle to the Earth is the Sun's Orbit; and the ſeven ſmall circles that are outmoſt, repreſent Saturn's Anomalies or different elevations, from his Perigeon to the Apogeon, together with his diurnal motion around the Earth, which is in the centre. The black circle in which the Sun is placed in the centre, ſhews the different Anomalies, and manner of Saturn's aſcending from his oppoſition to conjunction, and from conjunction to oppoſition again. And the figures 1, 2, 3, 4, around to 12, ſhew the order in which Saturn proceeds in his courſe, from one oppoſition to another. And, for example here, let Saturn be at figure 1ſt, he will then be ſeen in oppoſition to the Sun. And when he proceeds in his gradual aſcent to conjunction, from figures 1, 2, 3, to 4, he will, when at 4, be ſeen at a ſquare with the Sun. Again, when he proceeds from 4, 5, 6, to 7, he will, when at 7, be ſeen in conjunction with the Sun. And as Saturn deſcends from 7, 8, 9, to 10, he will, when at 10, be again ſeen at a ſquare with the Sun. And when Saturn proceeds from 10, 11, 12, to 1, he will then again be ſeen in oppoſition to the Sun. This circle repreſents Saturn's different Anomalies in his proceeding from one oppoſition to another, in the ſpace of a year and 13 days, which is the time of his Apogeon period. The which period, and the order in which Saturn appears in the Signs, we have deſcribed in the two former figures.

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And further, as these 7 circles, in this 5th figure, represent Saturn's different elevations from his Apogee to the Perigee, it requires 189 days or circulations of this Planet, around the Earth, from his opposition to his conjunction with the Sun; and the like number of days or circulations, between his conjunction and opposition. And therefore, the time between two oppositions of the Sun and Saturn, immediately following one another, computed according to their middle motions, is 378 days, or a year and 13 days; or between any to two similar Aspects or Elongations of Saturn from the Sun.

Now, after what we have here said concerning Saturn's motion about the Earth, and the order of his course, it may be said, by some, that this diurnal motion of Saturn around the Earth, requires two different modifications; viz. one from the Apogee to the Perigee, and from the Perigee to the Apogee again; and another through the Signs of the Zodiac, which will render the velocity of the Planet various, and different at different times.

As to this, it must be granted that it really is so, and is the Planets equations; for, when Saturn's motions are observed, and compared either with that of the Signs in the Zodiac, or with the Sun's, they do not agree in uniformity of velocity; for Saturn is seen sometimes to move equally with the Signs, and at other times to move slower than they do. And an inspection of figures 3d and 4th shews it to be so. But a more full answer will be given to this afterwards, when we come to describe the various velocity of the Moon in the firmament, together with the Satellites of Jupiter and Saturn.

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CHAP. XIX.

Shewing the equated times of Jupiter's moving through all the Signs of the Zodiac, and the time between two oppositions of the Sun and Jupiter.

BY the five figures above described, we have shewed the order of Saturn's passage thro' the signs of the Zodiac, and his different Anomalies and Equations, and manner of appearing in the signs, from one Apogeon to another, according to the Astronomical Tables; and also Saturn's diurnal motion around the Earth, with his different elevation or Anomalies, from betwixt his Perigee and Apogee, and his real and relative distance from the Sun therein. We come next to describe the order and manner of Jupiter's motion in the Heavens.

We shall begin then with Jupiter's diurnal motion about the Earth, and the order thereof from one Apogee to another, with his real and relative distance from the Sun therein, from figure 1. In this figure, the Earth is placed in the centre, the next circle is the orbit of the Sun, and the nine outmost circles shews the orbit of Jupiter in his different Anomalies, or different elevations, from the Perigee or opposition to the Apogee or conjunction; and the black circle of gradation, shews the circular distance that Jupiter keeps at from the Sun, from the Perigee, in his elevation, to the Apogee, and round to the Perigee again, from figures 1, 2, 3, all round to 12. Jupiter's mean distance from the Earth, is near five times greater than the Sun's distance from the Earth is; Plate 14. Jupiter's 1st Fig.

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and Saturn's mean diſtance being above nine times greater than the Sun's diſtance from the Earth is.

And let theſe 2 outmoſt circles repreſent Jupiter's gradual elevation from his Perigee to the Apogee, which takes Jupiter 199 days to accompliſh, and the like number of days from the Apogee to the Perigee again. Which, when taken together, is 398 days, or a year and 33 days, which Jupiter takes to compleat this period; or from any one period to another when compleated, according to the middle motion of this Planet. And when Jupiter, according to this figure, is in oppoſition, at 1, he is in or near the Perigeon; and when he proceeds from 1, 2, 3, to 4, and when at 4, he is ſeen at a ſquare with the Sun. Again, when he proceeds from 4, 5, 6, to 7, he will, when at 7, be ſeen in conjunction with the Sun; and, when in conjunction, he is in or near the Apogee. And as Jupiter deſcends from 7, 8, 9, to 10, he will, when at 10, be ſeen at a ſquare with the Sun. And Jupiter proceeds from 10, 11, 12, to 1, he will then again be ſeen in oppoſition to the Sun.

Plate 14. Jupiter's 1ſt Fig.

Now, after what has been ſaid, concerning Jupiter's diurnal motion about the Earth, and the manner of it, as deſcribed in this figure, and Saturn's diurnal motion, that we deſcribed in the laſt foregoing figure 5th, we ſhall here ſpeak a little of the reaſons of it, or certainty that it is ſo. The obſervations of all men teach and ſhew them the certainty that Jupiter and Saturn move, and appear to move, diurnally around the Earth, from the eaſt to the weſt, in the Firmament of Heaven. For if any of thoſe planet Stars be ſeen in the eaſt, at any certain time, 'gainſt the ſpace of 12 hours thereafter, they will be ſeen in the weſtern Hemiſphere. So likewiſe of the Sun; for if

the Sun be seen in the east at six o'clock in the morning, he will be seen in the western Hemisphere at six o'clock in the evening. The which sensible observation teacheth us, that the Sun and the Stars circulate every day around the Earth; for they appear to do so. And Astronomical observations also demonstrate, that when Jupiter or Saturn, for instance, are in or near their opposition, they appear larger and bigger than when they are in or near their conjunction with the Sun. This is known by the different angles in which Jupiter or Saturn is seen, when in conjunction or opposition. This difference of angles is so great, that Jupiter and Saturn must be the whole length of the Orbit of the Sun nearer the Earth, when they are in opposition or Perigee, than when they are in conjunction or Apogee.

In this diagram, Jupiter is just so much nearer the Earth in the opposition, than in conjunction, as seen at 1 and 7 in this diagram. And that Jupiter keeps his station in a circular manner about the Sun, in his gradual elevation from the Perigee to the Apogeon, hath been shewed in a similar way, by the manner in which Saturn proceeds in his course, according to the Astronomical Tables, from the figures 3d and 4th of that Planet; and will be further described from the following figures of this Planet.

We come to the 2d figure here, which shews the circular manner in which Jupiter proceeds around the Earth and Sun. As figure 1st shewed Jupiter's diurnal and circular motion about the Earth, and the manner of his proceeding about the Sun, in a circular distance from him in that course of the Planet, from opposition to conjunction, and from conjunction to opposition again, in his Apogeon period.

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This 2d figure ſhews the circular manner in which Jupiter keeps his ſtation all around, from one Perigee to another. In which circular courſe of proceeding in the Planet, the Sun is in the centre; and the Earth is eccentric in it, as much as the diſtance from the Sun to the Earth is. Which occaſions this, that Jupiter is ſeen apparently ſometimes to fall back ſeveral degrees in the ſigns of the Zodiac, although that his courſe in the Firmament, is perpetually forwards toward the weſt. For, let Jupiter be in the Perigee, as in figure 1ſt here, he not only makes a diurnal revolution about the Earth to the weſt, as deſcribed from figure 2d, but alſo proceeds in a circular manner about the Sun, towards the weſt, from one Perigee to another, in the ſpace of a year and 33 days. For, when Jupiter is in the Perigee, as at 1 in this figure, he proceeds from that to 2, then to 3, 4, 5, 6, 7, 8, in a circular manner, about the Earth and Sun, until he come to the next Perigee. But this proceeding of Jupiter towards the weſt, about the Earth and Sun, from one of his Perigeons to another, is the reaſon why he falls back towards the eaſt in the ſigns of the Zodiac. And in his doing ſo, he paſſes through them all in near the ſpace of 12 years; becauſe the conſtellations, or ſigns, compleat one courſe or circulation more than the Sun, in the ſpace of a year. And Jupiter takes one year and 33 days before that he compleats one courſe or circulation, more than the Sun doth.

Plate 14. Jupiter's 2d Fig.

After having premiſed theſe things we ſhall next ſhew the order of Jupiter's paſſing through the ſigns. And, for this purpoſe, we ſhall deſcribe Jupiter's paſſage through the ſigns of the Zodiac, from the year 1697 March 31ſt, to the year 1721 April 9th. In which

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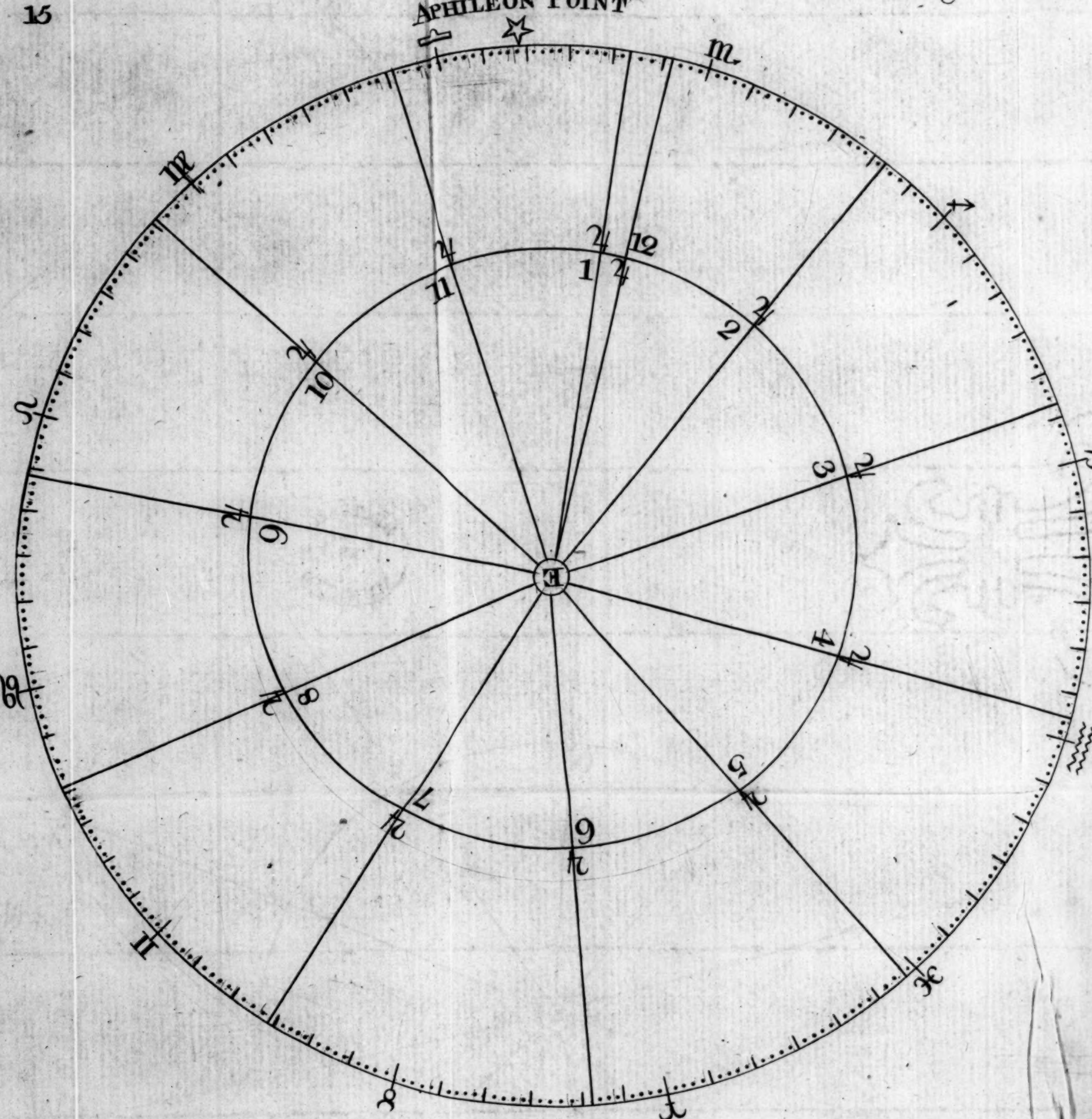
Fig 3 Jupiter



time Jupiter made two compleat revolutions through all the ſigns of the Zodiac, and 8 degrees of Libra more. And this we have taken from Dr. Halley's Aſtronomical Tables, for the foreſaid period of time. CHAP. XIX.

We ſhall then here explain Jupiter's 3d figure. In this figure, the twelve ſigns, are marked on the inſide of the outmoſt circle in their proper characters; and every ſign is divided on this circle into 30 degrees. The inmoſt circle ſhews Jupiter's paſſage in the Heavens, and the manner or place of his appearance in the ſigns, on which Jupiter is marked with his proper character, thus, ♃; and the Earth is placed in the centre at E; and Jupiter's Aphelial point is in the 9th degree of Libra; and the eccentricity of this Zodiac courſe is as 20,352, is to 426,000, or about a 20th part. Plate 15. Jupiter's 3d Fig.

This figure of Jupiter, ſhews us one compleat revolution that he made through all the ſigns of the Zodiac, and 14 degrees of Libra more, viz. from the 31ſt day of March 1697, to the 5th day of April 1709. To deſcribe this figure, and this revolution and period of Jupiter in particular: on the foreſaid year 1697 and 31ſt day of March, Jupiter was ſeen in the 22d degree of Libra. According to the foreſaid Aſtronomical Tables made for this Planet, and likewiſe, according to this figure, Jupiter, in his Orbit, is ſeen from the Earth in the centre at E, to appear in the 22d degree of Libra, as marked on the outmoſt circle; and the Radius line, drawn through the Planet's place at 1, doth ſhew the ſame. And on the 2d day of May, in the year 1698, Jupiter was ſeen in the 22d degree of Scorpio; and the Radius line, drawn through the Planet's place, ſheweth the ſame at 2, on the ſame outmoſt circle. And on the

CHAP. XIX. 4th day of June, in the year 1699, Jupiter was ſeen in the 24th degree of Sagittarius; and the ſtraight line, drawn through the Planet's place, at figure 3d, doth ſhew the ſame. On the 8th day of July, in the year 1700, Jupiter was ſeen in the 27th degree of Capricorn; and the ſtraight line, through the Planet's place at 4, doth ſhew the ſame. On the 14th day of Auguſt, in the year 1701, Jupiter was ſeen in the 2d degree of Piſces; and the 5th line, drawn through the Planet's place, ſheweth the ſame.

And likewiſe, on the 21ſt day of September, in the year 1702, Jupiter was ſeen in the 9th degree of Aries; and the next line, through the Planet's place at 6, ſheweth the ſame. On the 28th day of October, in the year 1703, Jupiter was ſeen in the 16th degree of Taurus; and the 7th line, through the Planet's place, ſheweth the ſame. On the 1ſt day of December, in the year 1704, Jupiter was ſeen in the 21ſt degree of Gemini; and the 8th line, through the Planet's place, ſheweth the ſame. On the 3d day of January 1706, Jupiter was ſeen in the 24th degree of Cancer; and the 9th line, through the Planet's place, ſheweth the ſame. On the 3d day of February 1707, Jupiter was ſeen in the 26th degree of Leo; and the 10th line, drawn through the Planet's place, ſheweth the ſame. On the 5th day of March 1708, Jupiter was ſeen in the 26th degree of Virgo; and the 11th line, through the Planet's place, ſheweth the ſame.

This figure ſheweth the place of Jupiter in the Signs for 12 years and 5 days, and he is hereby found to paſs through all the Signs of the Zodiac, and 4 degrees more, and contains 11 of his returns to the Perigee or oppoſition.

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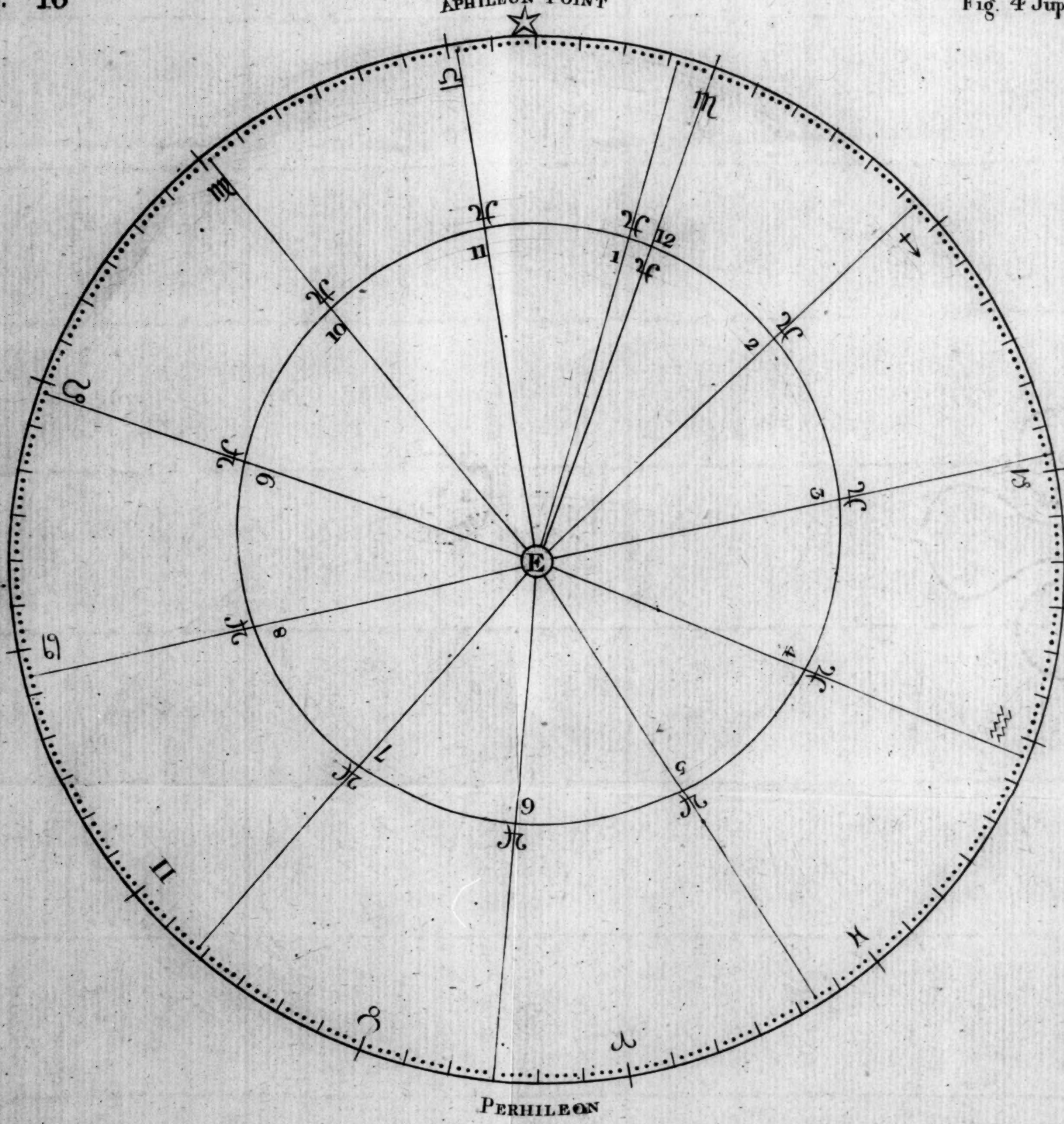
Fig. 4 Jupiter



We ſhall here likewiſe explain another of Jupiter's periods, in his paſſing through the Signs of the Zodiac, which is here reduced as the former is, under a Geometrical conſtruction, and repreſented by figure 4th. This figure is to be underſtoood, by the explication which was given of the laſt foregoing figure, they being exactly ſimilar in all reſpects. The Signs of the Zodiac, and the degrees of the Signs, are marked on the outmoſt circle; and Jupiter's place and character is marked on the inmoſt circle; and the Earth is in the centre at E.

CHAP. XIX.

Plate 16. Jupiter's 4 Fig.

We ſhall here begin Jupiter's paſſing in the Signs of the Zodiac, where it ended in the laſt figure. And, according to the foreſaid Aſtronomical Tables for this Planet, viz. in the 26th degree of Libra, in this diagram, and as ſeen at figure 1ſt, which the Radius line, from the Earth in the centre, pointeth to, and in which Jupiter was ſeen on the foreſaid 5th day of April, and year 1709, as the Table for this Planet for that day ſheweth. And on the 6th day of May 1710, Jupiter was ſeen in the 26th degree of Scorpio; and the 2d line, through the Planet's place, ſheweth the ſame. On the 9th of June, in the year 1711, Jupiter was ſeen in the 28th degree of Sagittarius; and the 3d line, through the Planet's place, ſheweth the ſame. On the 13th day of July, in the year 1712, Jupiter was ſeen in the 2d degree of Aquarius; and the 4th line, through the Planet's place, ſheweth the ſame. And on the 20th day of Auguſt, in the year 1713, Jupiter was ſeen in the 8th degree of Piſces; and the 5th line, through the Planet's place, pointeth to the ſame.

As alſo here, on the 27th day of September, in the year 1714. Jupiter was ſeen in the 14th degree

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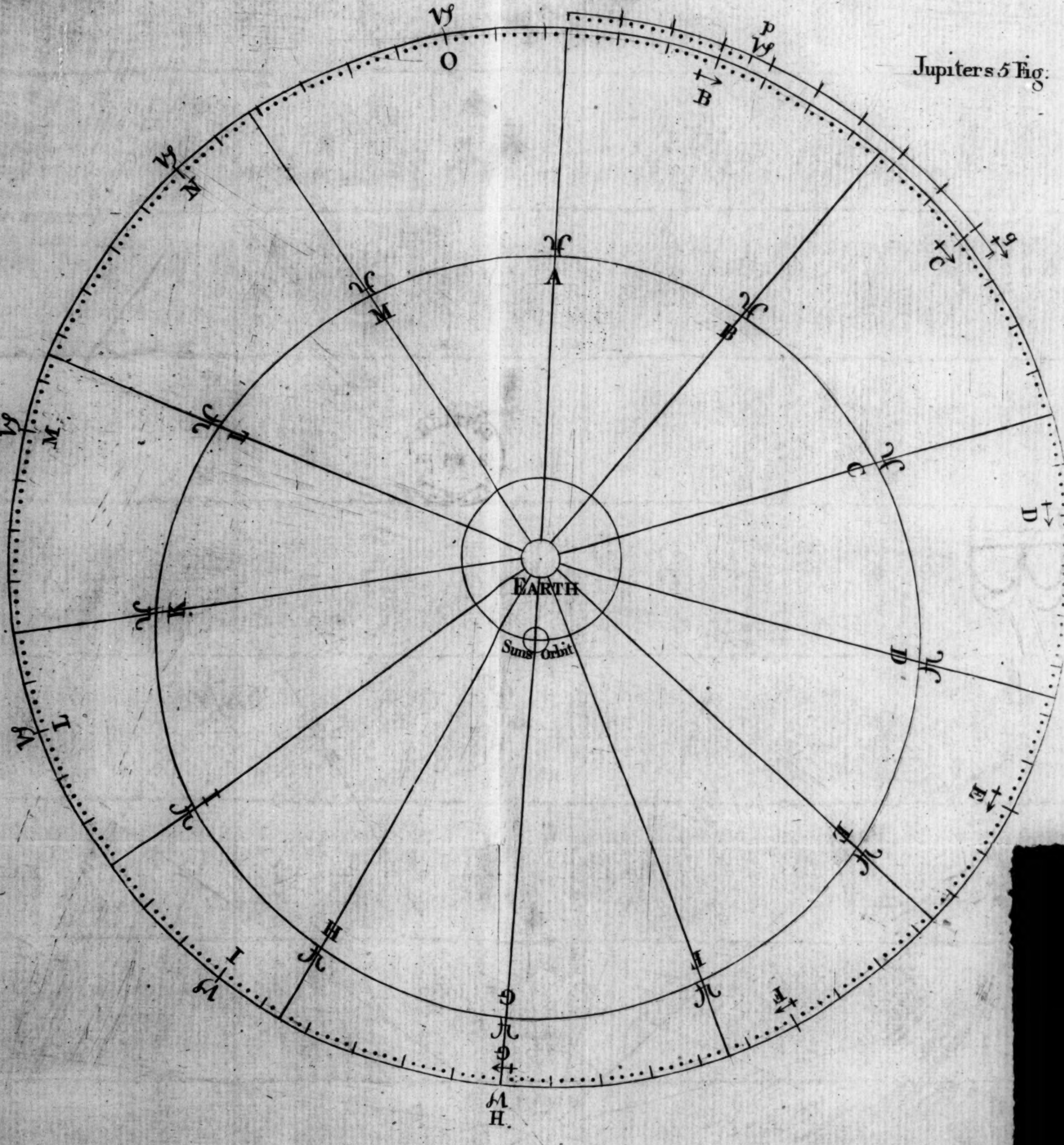
47 minutes of Aries; and the 6th line, through the Planet's place, ſheweth the ſame. And on the 2d day of November, in the year 1715, Jupiter was ſeen in the 21ſt degree of Taurus; and the 7th line, through the Planet's place, ſheweth the ſame. On the 6th day of December, in the year 1716, Jupiter was ſeen in the 26th degree of Gemini; and the 8th line through the Planet's place, ſheweth the ſame. On the 8th day of January, in the year 1718, Jupiter was ſeen in the 29th degree of Cancer, and the 9th line, through the Planet's place, ſheweth the ſame. On the 8th day of February, in the year 1719, Jupiter was ſeen in the 1ſt degree of Virgo; and the 10th line, through the Planet's place, ſheweth the ſame. And on the 9th day of March, in the year 1720, Jupiter was ſeen in the 1ſt degree of Libra; and the 11th line, through the Planet's place, ſheweth the ſame. On the 9th day of April, in the year 1721, Jupiter was in the 1ſt degree of Scorpio; and the 12th line, through the Planet's place, ſheweth the ſame. Jupiter having now compleated 1 revolution through all the ſigns, and 4 degrees more.

This figure, like the laſt figure above deſcribed, ſheweth the place of Jupiter in the Signs for 12 years and 4 days. And he is hereby found to paſs through all the Signs of the Zodiac, and 4 degrees more; and it contains 11 of his returns to the Perigee or oppoſition. And we alſo ſee, by the Aſtronomical Tables for Jupiter, that when he is in the Aphelion in Libra, he comes ſooner to an oppoſition with the Sun; and when he is in Aries in the Perihelion, he is longer in coming to an oppoſition. When Jupiter is in the Aphelion, he comes to an oppoſition with the Sun, in the ſpace of one year and 31 days. And

Pl. 17

Jupiters 5 Fig.



when he is in the Perihelion, he comes to an opposition in the space of 1 year and 37 days; and all between them in proportion. And this is locally represented to us, by the 3d and 4th figures of Jupiter, which, by inspection, may be easily understood. This difference, as to the times of Jupiter's coming to the opposition with the Sun, arises from the eccentricity of Jupiter's Zodiac course in the Heavens. And what we have said of Jupiter, is also true of Saturn in his Zodiac course.

And therefore, we have given the mean time of these Planets being exactly in any particular degree, of any Sign in the Zodiac. For Saturn and Jupiter may sometimes appear two minutes sooner in the Meridian, and at other times two minutes latter, than is, or can be represented by these figures of Jupiter and Saturn.

We have here shewed two of Jupiter's revolutions, in his going twice through the Signs of the Zodiac, and 8 degrees of Libra more, by the two foregoing figures, which he accomplished between the 31st day of March, in the year 1697, and the 9th day of April, in the year 1721, being the space of 24 years and 9 days, in which time, Jupiter made 22 returns to the Perigeon.

We shall next come forward here, and describe from the 5th figure, by way of example, Jupiter's place in the Zodiac, and in what Signs he was there, From one Perigeon or opposition, to another, which is here calculated from Monsieur De La Callie's Astronomical Tables of this Planet; and his several variations, backwards and forwards in the Signs, from the 5th day of June, in the year 1758, to the 10th day of July, in the year 1759, Jupiter being

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then partly in Sagittarius, and partly in Capricorn. And it is here to be considered, that altho' Jupiter takes 398 days from one of his oppositions to another, when computed according to the middle motion of this Planet, yet this period, that we are here describing, Jupiter was 400 days in finishing, except only a few hours. Because of his distance then from the Aphelial point, we shall here shew the manner of the figure.

Plate 17. Jupiter's 5th Fig.

In this 5th figure, the Earth is placed in the centre; the next circle shews the Orbit of the Sun, on which the Sun is marked thus ○; the second circle shews the Orbitual place and station of Jupiter, drawn near about its proportional distance from the Earth and Orbit of the Sun; in which Orbitual situation of Jupiter, the Sun is placed in the centre, tho' both of them circulate diurnally about the Earth; and the outmost circle shews the movement of Sagittarius and Capricorn, around the Earth and Sun, for 1 year and 33 days. This odd 33 days is carried on by the circular line on the outside from *p* to *q*; this outmost circle, with the addition of the said circular line for the 33 odd days, is divided into 12 equal parts, to correspond with Jupiter's period, in which time he returns from one opposition to another, at a mean computation as hath been said. For the Planet's time and circle are also divided exactly into twelve, and when this period of Jupiter, being 400 days, is divided by 12, it is 33 days and one third of a day.

In order then to describe more particularly this one Apogeon Period of Jupiter, let ABCDEFGHIKLM as marked on the inside of the second circle, point out the different places of Jupiter at 33 days distance, throughout the whole of this period. And also BC

DEFG be places of Sagittarius, at 33 days diſtance, and at the ſame times with Jupiter, as has been ſaid. And, ſince during the courſe of this period, Jupiter was partly in the conſtellations Sagittarius, and partly in Capricorn, and is always ſo in every period, when his conjunctions with the Sun happen to be in the beginning of Capricorn. Let then HILMNOP, as marked on the other ſide of the circle, be places of Capricorn, following about Sagittarius, in their Zodiac courſes, as they move to the weſt, and Jupiter along with them, and likewiſe, at 33 days diſtance; we make the calculation at 33 days, becauſe it divides Jupiter's aſcending and deſcending period in 12 equal parts; and Jupiter loſes but one circulation, and paſſes through all the Signs of the Zodiac, once in eleven years and 317 days time. We ſhall ſee here how much of it he loſes, and in what manner, during the courſe of this period, under our conſideration.

We ſhall here, in the deſcription, begin and proceed according to De La Callie's Aſtronomical Tables of this Planet, in this period. And on the foreſaid 5th day of June, in the year 1758, Jupiter was in oppoſition, and ſeen in the 15th degree of Sagittarius; and we ſee, by this figure here, that Jupiter, as marked at A, with his proper character thus ♃, is ſeen from the Earth in the centre, to appear in the 15th degree of Sagittarius, as marked thus ♐ at B on the outmoſt circle; and the Radius line, through the Planet's place, ſheweth the ſame. And on the 8th day of July next thereafter, or ſpace of 33 days, Jupiter was ſeen between the 11th and 12th degrees of Sagittarius, as marked at C; and the Radius line ſheweth the ſame, as it paſſeth through the Planet's place at B. And on the 10th day of Auguſt then next, or further ſpace of 33

CHAP. XIX. days, Jupiter was ſeen in the 10th degree of Sagittarius, as marked at D; and the Radius line, through the Planet's place at C, ſheweth the ſame. On the 12th day of September then next, or further ſpace of 33 days and one half, Jupiter was ſeen in the 12th degree of Sagittarius at E; and the ſtraight line, through the Planet's place at D, ſheweth the ſame. On the 16th day of October then next, or further ſpace of 33 days and one half, Jupiter was ſeen in the 17th degree of Sagittarius at F; and the ſtraight line, through the Planet's place at E, ſheweth the ſame. On the 18th day of November then next, or further ſpace of 33 days and one half, Jupiter was ſeen in the 23d degree of Sagittarius at G; and the ſtraight line, through the Planet's place at F, ſheweth the ſame.

And alſo further here, on the 22d day of December then next, and further ſpace of 33 days, Jupiter was ſeen in the 1ſt degree of Capricorn, as marked at H on the outſide of the circle. And here it is to be noted, that Jupiter is here fallen back from the conſtellation Sagittarius, into the 1ſt degree of Capricorn, according to the order of his courſe in the Heavens; and the ſtraight line, through the Planet's place at G, ſheweth the ſame; and alſo his being in conjunction with the Sun. And on the 24th day of January then next, or further ſpace of 33 days, Jupiter was ſeen in the 8th degree of Capricorn at I; and the next line, through the Planet's place at H, ſheweth the ſame. On the 26th day of February then next, or further ſpace of 33 days and one half, Jupiter was ſeen in the 15th degree of Capricorn at L; and the ſtraight line, through the Planet's place at I; ſheweth the ſame. On the 1ſt day of April then next, or further ſpace of 33 days, Jupiter was ſeen in the 20th

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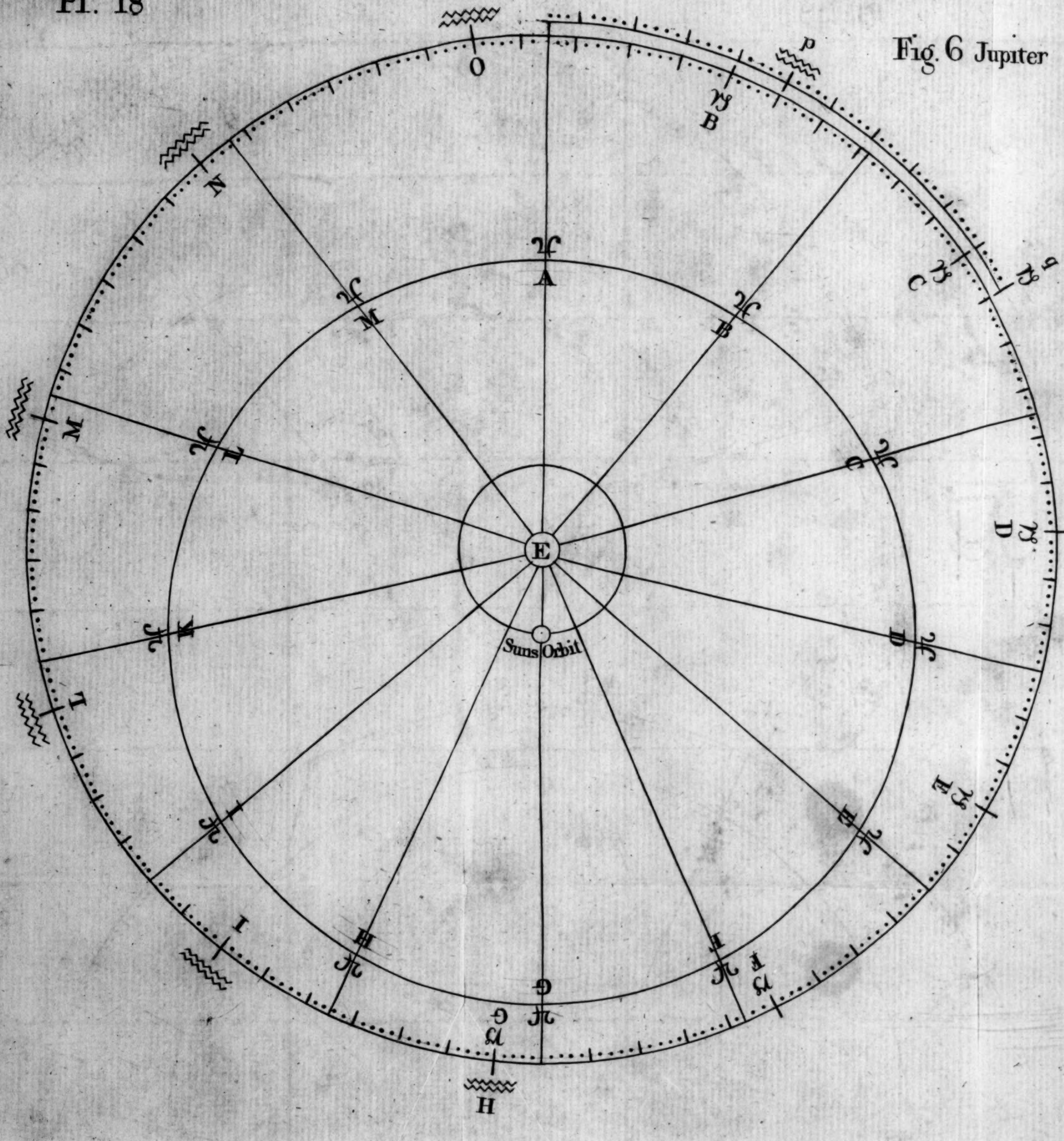
Fig. 6 Jupiter



degree of Capricorn at M; and the ſtraight line, through the Planet's place at K, ſheweth the ſame. On the 4th day of May then next, or further ſpace of 33 days and one half, Jupiter was ſeen in the 22d degree of Capricorn at N; and the ſtraight line, through the Planet's place at L, ſheweth the ſame.

And on the 6th day of June then next, or further ſpace of 33 days, Jupiter was ſeen in the 21ſt degree of Capricorn at O; and the ſtraight line, through the Planet's place at M, ſheweth the ſame. On the 10th day of July then next, or further ſpace of 33 days, Jupiter was ſeen in the 17th degree 42 minutes of Capricorn at *p*, as marked on the outſide of the circular line; and the ſtraight line at A, ſheweth the ſame; Jupiter being here again come to an oppoſition with the Sun. And it is here to be obſerved, that the Signs of the Zodiac, in the ſpace of this Perigeon period of Jupiter, which conſiſted of a year and 35 days, wanting only a few hours, gained one compleat courſe of the Sun, and thirty four degrees more. So that we ſee, in this figure, Sagittarius marked at B, in the firſt of Jupiter's oppoſitions, is removed about to *q* in the ſecond oppoſition; and all the other Signs in conformity thereto, which makes the order of the figure to be underſtood.

After we have ſhewed one of Jupiter's paſſages in the Signs, and order thereof, from one oppoſition to another, we ſhall next come to deſcribe a ſecond here, and that immediately following the other before mentioned; viz. from the 10th day of July, in the year 1759, to the 14th day of Auguſt, in the year 1760, as is repreſented here by Jupiter's 6th figure. This figure is conſtructed, juſt like the laſt above deſcribed. The Earth is placed in the centre; Plate 18. Jupiter's 6th Fig.

CHAP. XIX. the next circle ſhews the Orbit of the Sun about the Earth, in which he is marked thus ☉; the ſecond circle ſhews the Orbitual place and ſtation of Jupiter, drawn near about his proportional diſtance from the Earth, and Orbit of the Sun. In which Orbitual ſituation, and movement of Jupiter, the Sun is placed in the centre, and both of them are underſtood to circulate diurnally around the Earth, and appear to do ſo. And the outmoſt circle ſhews the movement of Capricorn and Aquarius in the Zodiac, around the Earth and the Sun, for the ſpace of 1 year and 35 days. Jupiter during the courſe of this period, was partly in Capricorn, and partly in Aquarius. And theſe 35 odd days being carried on by the circular line on the outſide from *p* to *q*, this outmoſt circle, with the addition of the ſaid circular line for the 35 odd days is divided into 12 equal parts, to correſpond with Jupiter's period, which was the time he required to proceed from the one oppoſition or Perigee, to the other, which is now under our conſideration. For the Planet's time and circle are alſo divided exactly into 12; and when this period of Jupiter, which was 400 days and ſome odd hours, is divided by 12, it is 33 days and one third part of a day.

For yet a more particular deſcription of this one Apogeon period of Jupiter, and the figure. Let ABCDEFGHIKLM, as marked on the inſide of the ſecond circle, point out the different places of Jupiter, at 33 days diſtance, throughout the whole time of this period; and alſo, BCDEFG be the places of Capricorn, at 33 days diſtance; and at the ſame times with Jupiter, as was ſaid. And ſince, during the courſe of this period, Jupiter was partly in the conſtellations Capricorn, and partly in Aquarius;

let then HILMNOP, as marked on the other ſide of the circle, be places of Aquarius, following about Capricorn in their Zodiac courſe, as they move to the weſt; and Jupiter, along with them in his courſe, and likewiſe at 33 days diſtance, which divides Jupiter's aſcending and deſcending period into 12 equal parts, as was ſaid. And as Jupiter loſes but one circulation, and paſſes through all the Signs of the Zodiac in ſomewhat leſs than twelve years time; we ſhall ſee here how much of it he loſes, and in what manner, during the time of this period, which we are here deſcribing.

We ſhall proceed in the deſcription, according as we did before, by De La Callie's Tables, for this Planet, in this period. On the foreſaid 10th day of July, in the year 1759, Jupiter was in oppoſition to the Sun, and ſeen in the 17th degree 42 minutes of Capricorn. And we ſee here, by this figure, that Jupiter, as marked at A, with his proper character, thus, ♃, is ſeen from the Earth in the centre, to appear in the 17th degree and 42 minutes of Capricorn, as marked at B, on the inſide of the outmoſt circle; and the Radius line, through the Planet's place, ſheweth the ſame. And on the 12th day of Auguſt then next thereafter, or ſpace of 33 days, Jupiter was ſeen in the 14th degree of Capricorn, as marked at C; and the Radius line, through the Planet's place at B, ſheweth the ſame. And on the 14th day of September then next, or further ſpace of 33 days and one half, Jupiter was ſeen in the 13th degree of Capricorn, as marked at D; and the Radius line, through the Planet's place at C, ſheweth the ſame. On the 18th day of October then next, or further ſpace of 33 days and one half, Jupiter was ſeen in the

CHAP. XIX. 15th degree of Capricorn at E; and the ſtraight line, through the Planet's place at D, ſheweth the ſame. On the 20th day of November then next, or further ſpace of 33 days, Jupiter was ſeen in the 20th degree of Capricorn at F; and the ſtraight line, through the Planet's place at E, ſheweth the ſame. And on the 23d day of December then next, or further ſpace of 33 days and one half, Jupiter was ſeen in the 27th degree of Capricorn, as marked at G, and the ſtraight line, through the Planet's place at F, ſheweth the ſame.

And further, on the 26th day of January then next, or further ſpace of 33 days, Jupiter was ſeen in the 5th degree of Aquarius, as marked at H, on the outſide of the circle; and the ſtraight line, thro' the Planet's place at G, ſheweth the ſame. And it is to be obſerved here, in this place of our figure, that Jupiter is here fallen back from the conſtellation Capricorn, into the 5th degree of Aquarius, according to the order of his courſe; and the Planet is alſo in conjunction with the Sun, or very near to it. And on the 28th day of February then next, or further ſpace of 33 days, Jupiter was ſeen in the 13th degree of Aquarius at I; and the ſtraight line, through the Planet's place at H, ſheweth the ſame. And on the 2d day of April then next, or further ſpace of 33 days and one half, Jupiter was ſeen in the 20th degree of Aquarius at L; and the ſtraight line, through the Planet's place at I, ſheweth the ſame. On the 7th day of May then next, or further ſpace of 33 days, Jupiter was ſeen in the 25th degree of Aquarius at M; and the ſtraight line, through the Planet's place at K, ſheweth the ſame. On the 9th day of June then next, or further ſpace of 33 days and one half, Jupi-

ter was ſeen in the 27th degree and 25 minutes of Aquarius at N; and the ſtraight line, through the Planet's place, ſheweth the ſame at L. On the 11th day of July then next, or further ſpace of 33 days and one half, Jupiter was ſeen in the 26th degree and 24 minutes of Aquarius at O; and the ſtraight line, through the Planet's place at M, ſheweth the ſame. And laſtly, here, on the 14th day of Auguſt then next, or further ſpace of 33 days, Jupiter was ſeen in the 22d degree 36 minutes of Aquarius at *p*, on the outſide of the circular line; and the ſtraight line, through the Planet's place at A, ſheweth the ſame. Jupiter being here come again to an oppoſition with the Sun, and very near his Perigeon diſtance from the Earth.

And it is here to be conſidered, that the Signs of the Zodiac, in the ſpace between this and the laſt preceding oppoſition of Jupiter and the Sun, gained one compleat courſe of the Sun, and near 35 degrees more. For the time, between this and the laſt oppoſition, conſiſted of 1 year 35 days and ſome odd hours. So that we ſee, in the figure, Capricorn as marked at B, in the firſt of Jupiter's oppoſitions, is removed about to *q* in the ſecond oppoſition, which is near 35 degrees more than a compleat circle. And all the other Signs in the Zodiac moved likewiſe in conformity thereto, which ſhews that this figure gives a viſible demonſtration of the order and manner of Jupiter's proceeding in his Orbitual courſe, in a regular manner; and yet, at the ſame time, is ſeen to appear as though he moved backwards at times; and, at other times, forwards through the Signs of the Zodiac.

And, although theſe figures of Jupiter and Saturn

CHAP. XIX.

above described, which sheweth the order of their course, from one Perigee or opposition to another, be only divided into twelve equal parts, and the one is taken at 33 days distance in the divisions of its time, and the other at 31 days distance, as to the times of its divisions; yet the places of them both may be found in the Signs of the Zodiac, for any one particular day that has intervened between the different times that we have fixed upon, in the description of the foresaid figures. And, though that we have given here but a few examples, in a Mathematical way of the times, and order of Saturn and Jupiter's proceeding through the Signs of the Zodiac, yet figures may be drawn, if they be properly constructed, and exactly divided according to the model of these above inserted, that will shew the places of Jupiter and Saturn in the Signs, not only for any particular period that is past, but likewise also, for any certain particular period of time that is to come; which gives a much more lively and proper idea of the movement of Saturn and Jupiter through the Signs, from one Tropic to another, and from one opposition to another, together with their whole train of attendants, these nine Satellites that accompany them in their circulations, through their different periods and appearances in the Heavens, than can be done by drawing circles, lines, and tangents, in a Geometrical way, to do it otherwise.

CHAP. XX.

CHAP. XX.

Of the Motion of the planet Mars, as to his circulation about the Earth, and relative Orbit about the Sun.

WE come next to deſcribe the Motion of the planet Mars, with its circulation about the Earth, and its relative Orbit about the Sun. This Planet is ſometimes much nearer to the Earth in its courſe than the Sun is; and ſometimes at a greater diſtance from the Earth than the Sun. For all the ſuperior Planets appear much bigger when they are in oppoſition to the Sun, than when they are in conjunction with him, being much nearer to the Earth in the one poſition, than in the other; inſomuch that the difference of their diſtances, in theſe two poſitions, is as great as the Orbit in which the Sun goes round the Earth, which difference bears a conſiderable proportion to the diſtance of Mars from the Earth, and greater in proportion than it does to the diſtances of the ſuperior Planets; and therefore, will produce a greater difference in his apparent magnitude. For Mars is five times nearer to us, when he is in oppoſition, than when he is in conjunction with the Sun. And therefore, ſince the viſible diſc and luſtre of a Planet increaſes in a duplicate proportion of that wherein the diſtance is diminiſhed, Mars will appear in proportion bigger and brighter when he is in oppoſition, than when he is conjunction with the Sun. And Mars when he is in an Acronychal poſition, that is, in oppoſition to the Sun, he is then five times nearer to the

CHAP. XX.

Earth, than when he is in conjunction with the Sun, as the Parallax ſheweth.

Plate 14. Mars's 1ſt Fig.

Let figure 1ſt repreſent Mars's different elevations, from his higheſt to his loweſt, in his diurnal courſe about the Earth from eaſt to weſt, in his period from one oppoſition or conjunction to another. For Mars moves about the Earth from eaſt to weſt, once a day; and ſometimes in his period, when in oppoſition, he is very near five times nearer to the Earth, than when he is in conjunction, as hath been ſaid. In this figure, the Earth is placed in the centre, and the five concentric circles, ſhew Mars's different elevations; for when Mars is neareſt the Earth, he moves about it, as circulating in the inmoſt circle; and when at his greateſt diſtance from the Earth, as circulating in the outmoſt circle, and all between them in proportion.

Plate 14. Mars's 2d Fig.

But to explain this a little further, Let figure 2d not only ſhew Mars's Orbit about the Earth, and his different elevations, but alſo his relative Orbit about the Sun, in his period, from one oppoſition to another, or one Perigeon to another. In this figure, the Earth is immoveable in the centre, and the inmoſt circle but one, ſhews the Orbit of the Sun about the Earth; and the five concentric circles, ſhew Mars's different elevations, from his being in the Apogee, until he come to the Perigee, as circulating from eaſt to weſt diurnally about the Earth; and the circle about the Sun, repreſents in ſome meaſure, the relative diſtance or Orbit of Mars about the Sun, from one conjunction to another, or oppoſition to another. This circle, in the figure, repreſents how that when Mars is in the Perigeon, or oppoſition, he is twice as near to the Earth, as the Sun is in his Orbit. And yet when in

the Apogeon, he is five times at a greater diſtance from the Earth, than when in the Perigeon. CHAP. XX.

The time between two oppoſitions of Mars and the Sun, are various; for ſometimes he will come to an oppoſition in 2 years and 33 days, and at other times it will be 2 years and 79 days, between one oppoſition and another, which occaſions that Mars will not be in the Perigee, preciſely at the time of every oppoſition with the Sun. This ariſes from the eccentricity of Mars's Orbit, and the Elliptical form of his relative courſe about the Sun.

Although we have deſcribed a circle in this figure, to repreſent, in a general manner, Mars's periodical courſe about the Sun, from one Perigeon or oppoſition to another; yet Mars's periodical courſe about the Sun, is carried on ſomething after the form of an Ellipſis, the which Ellipſis, when done on a fixed figure, is ſometimes in one poſition and ſometimes in another, which cauſes that it cannot be properly drawn on a fixed figure, therefore we are obliged to repreſent it by a circle.

But the track that Mars keeps, in paſſing through the Signs of the Zodiac, can be particularly deſcribed by a broad Ring, moving in a thick plate of braſs. The Signs and degrees, muſt be marked circularly around, on the braſs plate; and the times and places of the Planet, on the Ring. This Ring, moves twice about, and a ſixth part; or at ſometimes, a little leſs or more, for to bring Mars to an oppoſition or conjunction with the Sun, becauſe Mars is ſome weeks longer in coming to a conjunction, than he is at other times, and the eccentricity of the Planet's Orbit is to be taken, and his proper diſtance from the Aphelial point, as we have done, in the examples which we

CHAP. XXI. have given, to ſhew the places of Jupiter and Saturn. And this will ſhew Mars's place in the Signs, at any given time, very near according to the Aſtronomical Tables.

CHAP. XXI.

Of the Motion of Venus about the Earth, and her relative Orbit about the Sun.

WE come next to deſcribe the Motion of the Planet Venus, with her Orbit about the Earth, and alſo her relative Orbitual courſe about the Sun. Venus does nearly keep always the ſame diſtance from the Sun, yet ſhe is continually changing her diſtance from the Earth; and her diſtance is greateſt, when ſhe is in her ſuperior conjunction with the Sun, and it is leaſt, when ſhe is in her inferior conjunction; and the difference is ſo great, that it equals the whole diameter of Venus's Orbitual relative courſe about the Sun. So that the diſtance of Venus from the Earth, when ſhe is in her ſuperior conjunction, is to her diſtance in the inferior, as 1 is to 6; therefore, Venus approaches the Earth, ſix times nearer in the one poſition than in the other. And juſt ſo much are the apparent diameters of Venus changed, according to obſervation. But theſe greateſt and leaſt diſtances are ſomewhat changeable, for Venus is then moſt remote from the Earth, where the ſuperior conjunction happens, when Venus and the Sun are both in the Apogee, and the diſtance of Venus from the Earth is leaſt of all, when the inferior conjunction falls out, when Venus and the Sun are both in the Perigeon.

Let figure 1ſt repreſent Venus's different elevations,

Plate XIX.

Fig: 2.

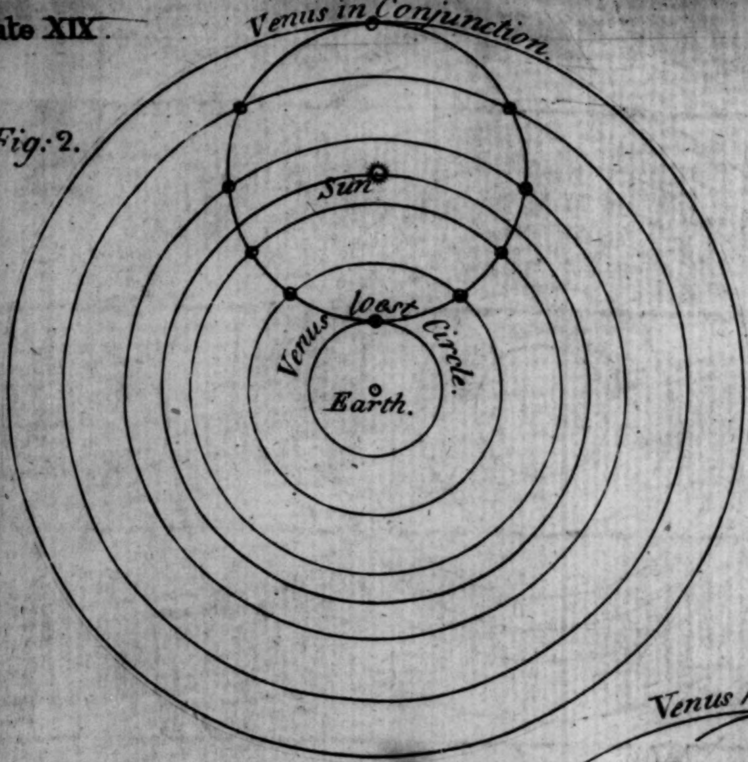


Fig: 1.

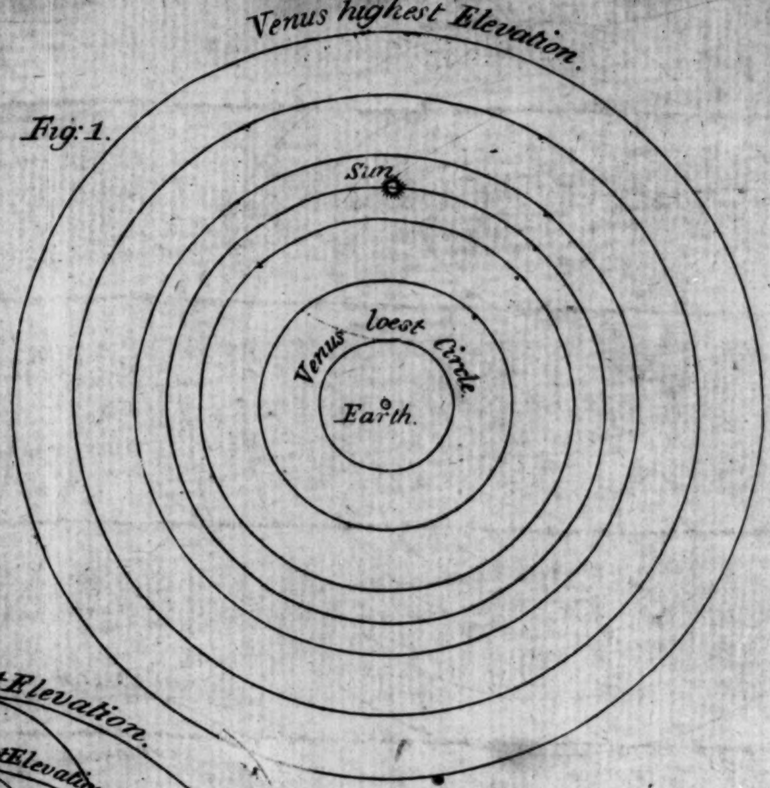


Fig. 3.

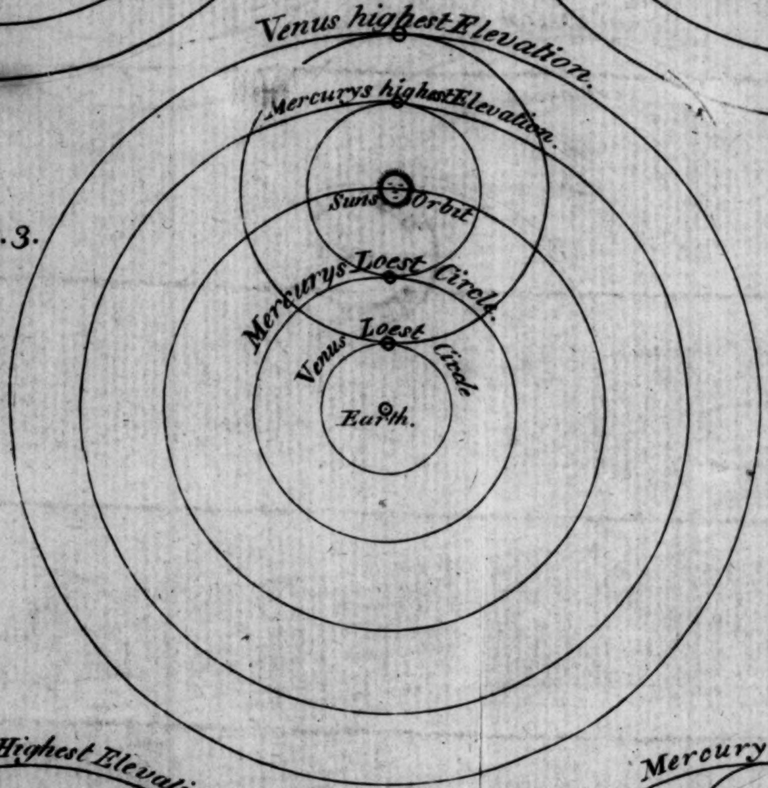


Fig. 1.

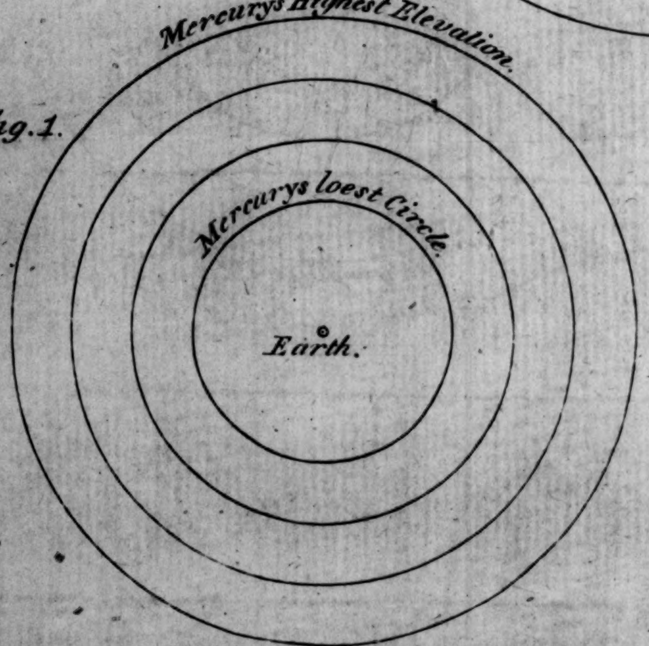
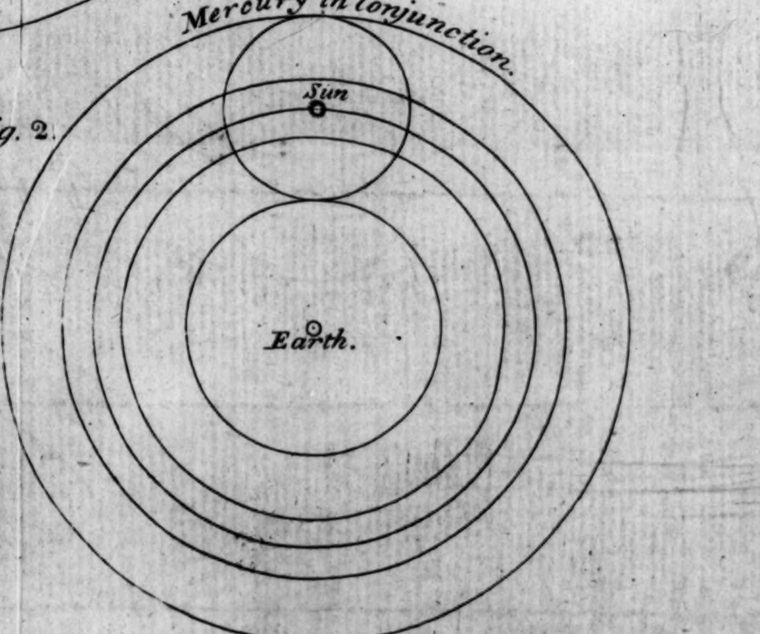


Fig. 2.



from her higheſt to her loweſt circle, in her diurnal revolutions around the Earth, from eaſt to weſt. In this figure, the Earth is placed in the centre, and the ſix concentric circles ſhew Venus's different elevations from her Perigeon to her Apogeon. For when Venus is neareſt the Earth, ſhe revolves about it, as circulating in the inmoſt circle; and, when at her greateſt diſtance from the Earth, as circulating in the outmoſt circle, and all between them in proportion, according to the times thereof. CHAP. XXI. Plate 19. Venus's 1ſt Fig.

And to explain this more fully, let figure 2d both ſhew Venus's Orbit about the Earth, and her different elevations; and alſo, her relative Orbitual courſe about the Sun, in her period, from one inferior conjunction to another. In this figure, the Earth is immoveable in the centre; and the fourth circle, from the centre, ſhews the Orbit of the Sun about the Earth; and the ſix concentric circles, ſhew Venus's different elevations, from her being at an inferior conjunction with the Sun, until ſhe come to a ſuperior conjunction, as circulating diurnally about the Earth. And the other circle, that is deſcribed about the Sun, repreſents the relative diſtance or Orbit of Venus about the Sun, from one inferior conjunction to another. This circle, in the figure, ſhews, how that when Venus is at an inferior conjunction with the Sun, ſhe is near four times nearer the Earth than the Sun is in his Orbit. And when ſhe is at her ſuperior conjunction, ſhe is near ſix times at a greater diſtance from the Earth, than when at her inferior conjunction, being then four times more diſtant than the Sun. Venus's 2d Fig.

The time between two conjunctions of Venus and the Sun, of the ſame kind, computed according to the

CHAP. XXI. middle motion of the Planet are 533 days. But theſe conjunctions, as here computed, are variable; becauſe Venus and the Sun are carried in Orbits that are ſomething of an Elliptical form, in which their motions are conſtantly varying, ſometimes going faſter, and ſometimes ſlower. It may be, that the true conjunctions ſhall happen ſome few days ſooner or latter than the computation that we have given.

But the track that Venus keeps, in paſſing through the Signs of the Zodiac, either in her declinations ſouth or north, or in her returns from one inferior conjunction to another, can be more properly delineated by a broad ring, moving in a thick plate of braſs, where the Signs and degrees are marked circulary on the plate, and the times and place of the Planet on the ring, than it can be done on a fixed figure; becauſe Venus paſſes much more rapidly through the Signs than Jupiter and Saturn doth, and deſcribes the form of an Elliptical figure, in her relative courſe about the Sun.

Becauſe Venus is an opaque body without any light of her own, and only ſhines with the borrowed light of the Sun, that face of Venus will only appear bright, which is turned towards the Sun, while the oppoſite remains in darkneſs, and for want of light is altogether inviſible. Wherefore, if the ſituation of Venus be ſuch, that the dark ſide be turned towards the Earth, Venus will become inviſible, except by chance, ſhe appear like a black ſpot in the Sun's diſc. But if the whole illuminated face of Venus be turned towards the Earth, as it is when ſhe is near her ſuperior conjunction, then ſhe appears like a full ſhining Orb. And according to the different poſitions of Venus and the Sun, Venus will have dif-

ferent forms, and appear with different faces and figures, and will undergo the ſame changes and viciſſitudes in her appearances, that the Moon does.

It is found by obſervation, and this figure doth ſhew, that the greateſt elongation of Venus from the Sun, either when ſhe is before or behind him, is about 48 degrees. And it is alſo manifeſt, that Venus, from the time of her ſuperior conjunction, where ſhe is fartheſt from the Earth, to the time of her inferior conjunction with the Sun, where ſhe approaches neareſt it, is always ſeen more eaſterly than the Sun; and all that time Venus ſets latter than the Sun, and is ſeen after ſun-ſetting, and then ſhe is called the Evening Star, or Veſperus, being a forerunner of night and darkneſs. But from the inferior conjunction, till ſhe comes again to the ſuperiour, ſhe is always obſerved to be to the weſtward of the Sun, and conſequently muſt ſet before him in the evening, and riſe before him in the morning; and then ſhe is only to be ſeen before Sun-riſing, when ſhe is called the Morning Star, or Phoſphorus, her appearance foretelling that light and day are near approaching.

CHAP. XXII.

Of Mercury's Motion about the Earth, and relative Orbit about the Sun.

WE proceed further, to deſcribe the courſe of the planet Mercury in his Orbit about the Earth, and his periodical courſe about the Sun. This Planet circulates about the Earth once a-day, and in a mean period of 116 days he has a relative

CHAP. XXII.

course about the Sun, being sometimes before, and sometimes behind him; and likewise at an inferior conjunction, and superior conjunction with the Sun. And when Mercury is at an inferior conjunction, he is nearer the Earth than when he is at a superior conjunction with the Sun. The difference of these two positions, being nearly as 6 is to 15. For when the track of Mercury's course about the Sun, is taken in a circular manner, and when he is at an inferior conjunction, he is distant from the Earth 6 of those parts, whereof the superior conjunction's distance makes 15.

Plate 19. Mercury's 1st Fig.

Let figure 1st, represent the course of Mercury about the Earth. The Earth is placed in the centre of this figure, and the four concentric circles shew Mercury's different elevations, from the inferior to the superior conjunction of the Planet. The inmost circle shews Mercury's course about the Earth, on the day of his inferior conjunction. And the outmost circle shews his course at the superior conjunction, and these between them in proportion, according to the times thereof.

Plate 19. Mercury's 2d Fig.

And further, Let figure 2d shew both Mercury's Orbit about the Earth in his different elevations, and his relative course about the Sun, in his period from one inferior conjunction to another. In this figure, as in the former, the Earth is placed in the centre, and the middlemost circle shews the Orbit of the Sun, and the other four concentric circles represent Mercury's different elevations, from his being in the inferior conjunction, until he come to a superior conjunction with the Sun, in the Planet's revolving daily about the Earth. And the other circle that is described about the Sun, shews the Orbit or track of

Mercury about the Sun, in the Planet's period from one inferior conjunction to another. And the time between two conjunctions of Mercury and the Sun, of the same kind, computed according to the middle motion of the Planet, are 116 days. But these conjunctions are variable, upon account of the Planet's eccentricity, and the Elliptical form of the Orbit that he describes about the Sun; which is the reason, that the conjunctions happen sometimes eight days sooner, and sometimes eight days latter, than the computation we have given. CHAP. XXII.

Mercury keeps always in the neighbourhood of the Sun, and never recedes from him so far as Venus does, and is so much hid by the splendor of the Sun's rays, that he is but seldom seen. For his greatest elongation from the Sun, at his greatest distance, when he is before, or behind the Sun, is but 22 degrees and one half; and never above 46 times the the Sun's breadth from his centre. But when Mercury is so far from the Sun's rays as to be seen, he appears with such brightness as to outshine all the other Planets.

CHAP. XXIII.

Of the order of Venus and Mercury's Motion about the Earth and the Sun.

WE shall next shew Venus and Mercury's Orbits about the Earth, and their relative tracks that they keep about the Sun, from figure 3d. In this figure, the Earth is in the centre, and the middlemost circle is the Orbit of the Sun. The inmost circle Plate 19. Venus and Mercury's 3d Fig.

CHAP. XXIII. ſhews the revolving of Venus about the Earth, at her inferior conjunction. And the outmoſt circle her courſe, when at her ſuperior conjunction with the Sun. And the inmoſt circle but one, ſhews Mercury's revolving about the Earth, when at his inferior conjunction. And the outmoſt circle but one, his courſe when at his ſuperior conjunction with the Sun. And the intervening lines or ſpaces between them, in proportion according to the times.

Let the inmoſt circle deſcribed about the Sun, repreſent Mercury's Orbitual courſe about the Sun, in his Apogeon period, and the outmoſt circle about the Sun, repreſent Venus's Orbitual courſe about the Sun. Theſe circles, that are deſcribed about the Earth in the figure, ſhew the Planets diurnal motion about the Earth; and thoſe circles about the Sun, ſhew the Planets periodical Apogeon courſe around the Sun; and alſo ſhew that the Planets do not move with the ſame velocity one day with another, during the courſe of any one period of their departing from, and returning to the Perigee; and that they not only appear, but alſo realy do ſometimes move faſter and ſometimes ſlower in their courſe around the Earth. But this will be deſcribed more fully afterwards.

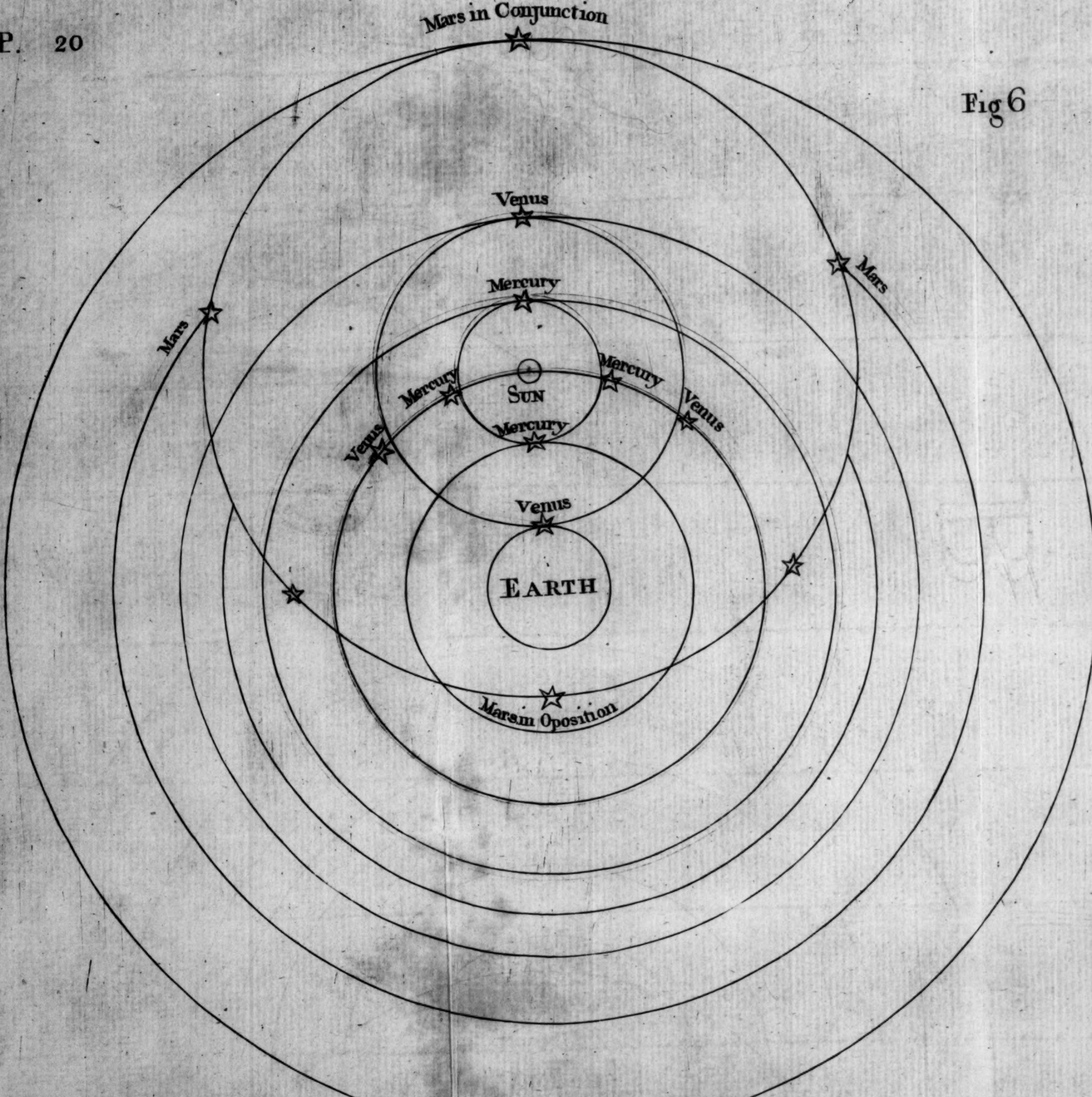
CHAP. XXIV.

Of the order of Mercury, Venus and Mars's Motion about the Earth and Sun.

WE come next here to ſhew, Mercury, Venus and Mars's Orbits about the Earth, and their

P. 20

Fig 6


Mars in Conjunction
Venus
Mars
Mars
Mercury
Mercury
Mercury
Sun
Venus
Venus
Mercury
Venus
Earth
Mars in Oposition

different anomalies, together with their diſtance from the Sun, and one another in their Orbits, either when in their Apogee or Perigee, or at a ſquare, from the 6th figure. In this figure, the Earth is placed in the centre. The inmoſt circle, around the Earth, ſhews the courſe of Venus when at an inferior conjunction. The outmoſt circle but two, ſhews Venus's courſe when at her ſuperior conjunction with the Sun. And the inmoſt circle but one, is Mercury's courſe around the Earth, when at his inferior conjunction with the Sun. And the circle, next above the Sun's Orbit, ſhews Mercury's courſe when at his ſuperior conjunction. And the inmoſt circle but two, about the Earth, ſhews the Orbit of the Sun. And the point marked thus * ſhews the diſtance of Mars's circulation around the Earth, when ſhe is in oppoſition to the Sun. And the outmoſt circle about the Earth, ſhews the courſe of Mars when he is in conjunction with the Sun. And again, the inmoſt circle that is deſcribed around the Sun, in this figure, repreſents Mercury's Orbitual courſe about the Sun in his Apogeon period. And the next circle about the Sun, ſhews Venus's Orbitual courſe about the Sun. And alſo, the outmoſt circle about the Sun, repreſents Mars's Orbitual courſe about the Sun, Mercury, Venus and the Earth.

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Plate 10. Venus, Mercury and Mars's 6th Fig.

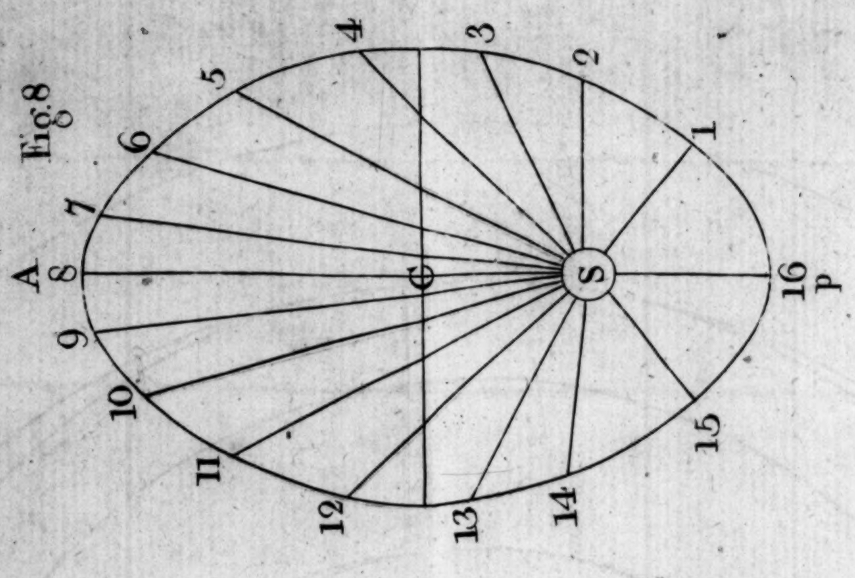
This figure ſhews, that although theſe three Planets, Mercury, Venus and Mars, move about the Earth diurnally in circles, ſometimes nearer, and ſometimes at a greater diſtance from it; yet they never interfere with each other, or come near to one another's bodies, nor with the Sun. For Mercury, who keeps neareſt to the Sun, is always above 22 degrees from his body; and Venus, who is ſtationed next to Mercury, yet ſhe is always above 24 degrees di-

CHAP. XXIV.

ſtant from Mercury. And likewiſe Mars, although he be nearer to the Earth when he is in oppoſition to the Sun, than Mercury is, when he is in his inferior conjunction with the Sun; yet Mars, when he is in his loweſt circle, and neareſt to the Earth, is then in oppoſition to the Sun, and almoſt in the oppoſite point of the Heavens to Mercury and Venus. And in circular, or even in Elliptical Orbits, Mars is much more diſtant from Venus, than Venus is from Mercury, either when he is in oppoſition, at a ſquare, or in conjunction with the Sun.

The relative courſe of theſe three Planets, Mercury, Venus and Mars, about the Sun, appears in the figure, as when they are under one Latitude; which they very ſeldom are all under at the ſame time, becauſe of the Planets Latitude from the Sun. But I have not attempted to give the regular courſes, according to equalled times, of Mercury, Venus and Mars, through the Signs of the Zodiac, as I have done of Saturn and Jupiter, (but only their mean motion) becauſe theſe three Planets paſs much more rapidly through the Signs, between one oppoſition or conjunction, and another, than Saturn and Jupiter do. Therefore, their uniform regular courſes may be delineated on moveable figures, but cannot be deſcribed upon fixed copper-plates, as Jupiter and Saturn's are.

Fig. 8



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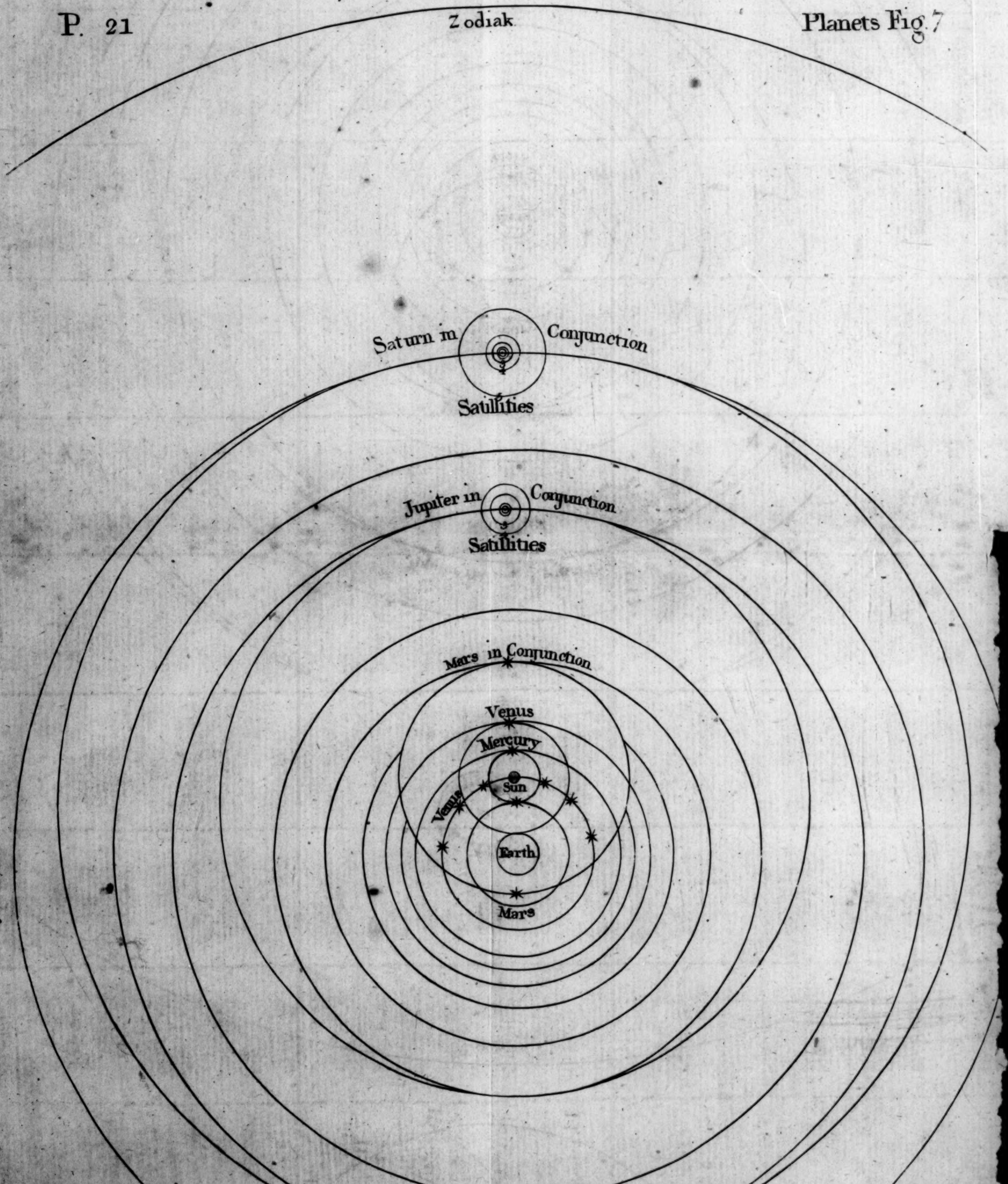
Planets Fig. 7



CHAP. XXV.

CHAP. XXV.

A Description of all the five Planet-Stars, shewing the Order of their Motion about the Earth, and Orbits about the Sun.

ONCE more, we shall next here shew all the five Planet-Stars in their Orbits about the Earth, and their different elevations and anomalies, together with their proper distance from the Sun, and one another, in their Orbits, either when in their Apogee or Perigee, from figure 7. In this figure, the Earth is placed in the centre, and the inmost circle but two, shews the Orbit of the Sun about the Earth. And as to the three Planets, Mercury, Venus and Mars, in their Orbits, as here shewn in the figure, they are the same with what was represented of them in the 6th and last figure, of which we gave a short description, and to which we here refer. The outmost circle about the Earth, shews the course of Saturn, when he is in the Apogee or conjunction with the Sun. And the next outmost circle about the Earth, shews the course of Saturn, when he is in opposition to the Sun. And that circle which is described about the Sun, represents Saturn's elevation, and Orbitual course about the Sun, and the other Planets, in his Apogeon period, from one opposition to another. The outmost circle about the Earth but two, shews Jupiter's course when he is in conjunction with the Sun, and in the Apogee. And the next circle within that, about the Earth, shews the course of Jupiter when he is in the Perigee, or opposition to the Sun. And that circle,

Plate 21. Fig. 7. Of the 5 Planets.

CHAP. XXV. which is deſcribed about the Sun in Jupiter's place, repreſents Jupiter's elevation, and orbitual courſe about the Sun, and inferior Planets.

This figure, like the other that we laſt deſcribed, ſhews that the five primary Planets, together with the Satellites of Jupiter and Saturn, in all their different elevations, never come near to touch one another's bodies, or interrupt one another in their courſes, although they were all moving in the Equator, which they ſeldom or never do at the ſame time.

And in this figure, the orbits of Jupiter and Saturn are drawn too near to the Earth, in proportion to the other Planets of it, and their reſpective Satellites are, at the diſtance from their bodies, in the following proportion. For the firſt Satellite of Jupiter, is only diſtant from his body 2 $\frac{1}{2}$ of his own diameters. The ſecond, is diſtant 4 $\frac{1}{2}$ diameters. The third is removed from Jupiter 7 of his diameters. And the fourth and outmoſt, is at the diſtance of 12 diameters of Jupiter.

As alſo, as to the diſtance of Saturn's Satellites from his body, it is in the following proportion. The firſt Satellite of Saturn, is diſtant from Saturn's centre 4 $\frac{3}{8}$ of his ſemidiameters; and the ſecond is at the diſtance of 5 $\frac{3}{5}$ of Saturn's ſemidiameters; the third is at the diſtance of 8 ſemidiameters; the fourth is at the diſtance of 18 of Saturn's ſemidiameters; and the fifth and outmoſt Satellite, is 54 ſemidiameters of Saturn, diſtant from him. So that theſe two Planet-Stars, Jupiter and Saturn, with their reſpective Satellites which are ſo near them, (as has been ſaid) cannot in any direction, or oppoſition in their orbits whatever, interfere with, or diſturb the other Planets in their courſes.

This method of drawing the courſes and Orbits of the Planets, is demonſtrable by Aſtronomical obſervations, and is moſt agreeable to the viſible appearances, we have of them, in their diurnal motion weſtwards about the Earth; and by it we can ſolve the whole phenomenon of the Planets motions diurnally from eaſt to weſt, either as to their direct motions, or their ſtations and retrogradations, and of the inequality of their motions either real or apparent.

And if it ſhall be objected againſt the whole of this ſcheme of deſcribing the Orbits and courſes of the Planets, becauſe it ſhews us, that the Planets motions are not uniform with the other Stars in the Firmament of Heaven, and that they do not move with the ſame velocity, one day with another, in their different periods. But let it be obſerved, that in drawing and deſcribing the order of their courſes, we muſt do it according to the model of the Heavens. And even the Sun's motion over the Meridian, is not perfectly uniform and equable, depending on two cauſes, namely, the obliquity of the Ecliptic, and the Sun's unequal motion in it, which is occaſioned by the eccentricity of his Orbit, which we ſhewed before, when we ſpoke of the Equation of time.

And even thoſe who are for the Earth being in motion, muſt allow, either the Earth or the Sun to have ſuch a motion, as not to deſcribe equal hours on a Sun-dial preciſely, according to equal time. And all Planet Stars, although they do not paſs over the Meridian of the Earth equably, according to equated time, yet their motions are regulated by a certain uniform law, from which they never deviate. For the time and manner of their motion around the Earth, is regulated by two modifications; namely,

CHAP. XXV. their different eccentricities and periods of paſſing through the Signs of the Zodiac, between the Tropics; and alſo their different periods and times of their returning from one Perigeon to another, which is the cauſe of the inequality as to the times of the Planets paſſing over our Meridian, examples of which we have given already in our deſcriptions of the motions of the Planets Jupiter and Saturn, and of the figures of Mars, Venus, and Mercury.

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Of Mr. Kepler's deſcription of the Motion of the Planets in their Orbits.

AND no ſcheme of Aſtronomy has hitherto been found out, wherein the Mathematicians can deſcribe either circular or Elliptical Orbits, wherein the Planets do move uniformly and equably all around in their periods; becauſe this is not agreeable to the laws of the Planets motions, and therefore, impoſſible to deſcribe. Thoſe who write upon the Copernican ſcheme, ſay, that the motion of a Planet, in the Periphery of an Ellipſis, is not at all equable; yet it is regulated by a certain immutable law, from which it never deviates, which is, that a line or ray, drawn from the centre of the Sun, to the centre of the Planet which is carried about with an angular motion, does ſo move, that it deſcribes, or ſweeps an Elliptical area always proportionate to the time. Let therefore (as they ſuppoſe) figure 8th, be the form of the Orbit which the Planets deſcribe; yet the place of the Sun, is not the centre of it, but he takes his reſidence in one of the focuſes of it, as at S, and C is

Plate 21. Fig. 8. the ſuppoſed motion of a Planet.

the centre. And the diſtance SC, between the Sun in the focus and the centre, is called the eccentricity; and the line AP, is called the line of Apſides; and the point A, is termed the higher Apſis and the Aphelion, the point P is called the lower Apſis and the Perihelion. Now, in order to divide the area of the Ellipſis proportionally to the time, let the Planet ſet out from the Perihelion, at the point P, where it is neareſt the Earth, and move on to figure 1ſt, and then through the figures 2, 3, 4, 5, 6, 7, to 8, and when it is at 8, it is at the Aphelion, and greateſt diſtance from the Sun. Thus the triline area S 16 1, is equal to the area S 7 8; and all the others between 1 and 7, in a reciprocal proportion to their diſtance from the Sun. And thus, when the Planet moves one round from A to P, thro' the figures 9, 10, 11, 12, 13, 14, 15, to 16, and that the area of the Ellipſis be equally divided from the eccentric focus, the arches, that the Planet deſcribes, muſt be unequal, all round in its Elliptical orbit.

Mr. John Kepler, in his commentaries on the planet Mars, was among the firſt that invented this method of the deſcription of the motion of the Planets in their Orbits, that a line or ray, drawn from the centre of the Sun, to the centre of the Planet which is carried about with an angular motion, does ſo move, that it deſcribes or ſweeps an Elliptical area, always proportional to the time. And unto this invention of Kepler's, many Aſtronomers ſince, give their conſent; becauſe they found no other rule (according to their ſcheme of Aſtronomy) which ſatisfies all the appearances of the Planets motions.

But, we ſee from this ſcheme of the Planet's motions, in their orbits, which was invented by Mr. John Kepler, and others, that even, according to it, the

CHAP. XXVI. Planets do not move uniformly and equably, all around in their periods; but that they ſometimes quicken, and at othertimes ſlacken their velocity in their courſe. But we have before demonſtrated, that this quickening or ſlackening of a Planet's motion, ariſes, and is occaſioned from a certain modification of the Planet's moving circularly around the Firmament of Heaven.

But, againſt this ſcheme of Keplers, in deſcribing that the planet Stars have no diurnal motion around the Earth, but only an Elliptical motion about the Sun, in their different periods; and that the Sun hath not his reſidence in the centre of the Ellipſis, but has his place in a certain focus, in one end of the Planets Elliptical orbits. We ſay, againſt this ſcheme, amongſt many other things, we have this exception, that the very form of the figures that are made out to repreſent this, are not calculated to ſatisfy the genius of a Mathematician, as ſuch. That any immoveable body ſhould have other bodies permanently moving about it, and yet itſelf not to be in the centre of their orbitual courſe.

And that the Sun ſhould be ſuppoſed and eſteemed to have the planet Stars moving and circulating around him, as tho' he were the only centre of their motions, and not the Earth. For, whereas in very deed, the Sun is not the centre of the Planets real motion, whether conſidered as circular or Elliptical. But, beſides this, that ſcheme ſuppoſes that the Earth muſt have and take its courſe with the planet Stars around the Sun, in the Firmament of Heaven, which is contrary to the common ſenſe of mankind, and to the truth, when they are viewed and contemplated with the proper inſtruments that regulate the refraction.

PLATE. XXII.

Fig. 1.

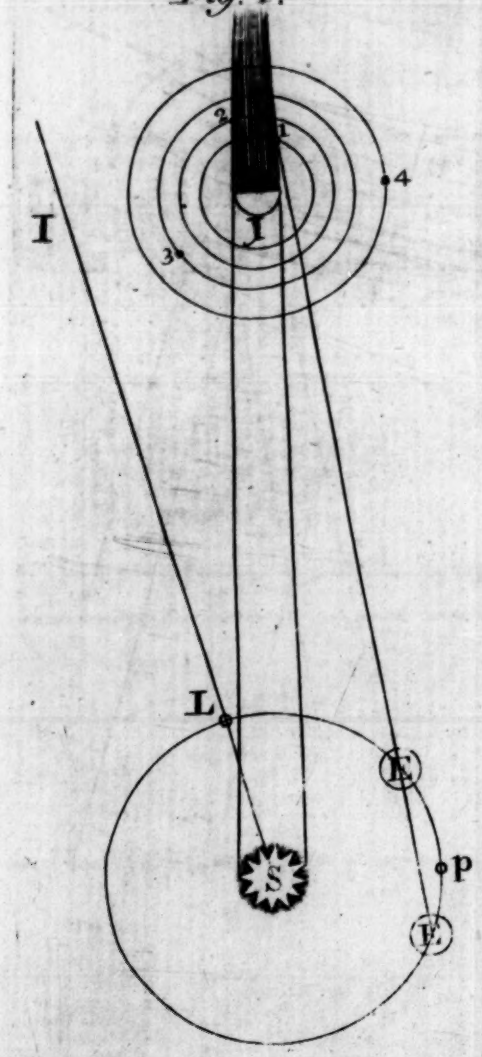
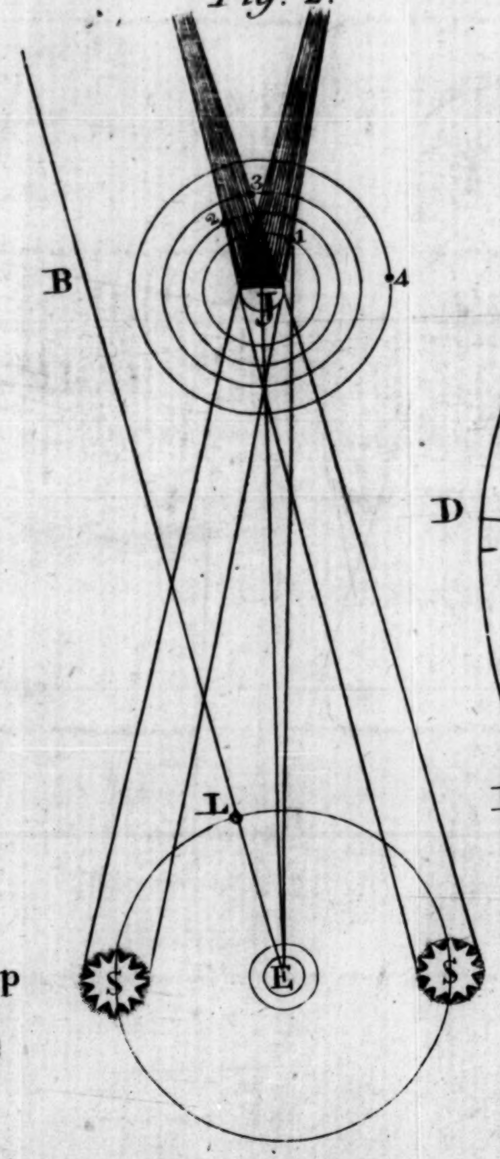
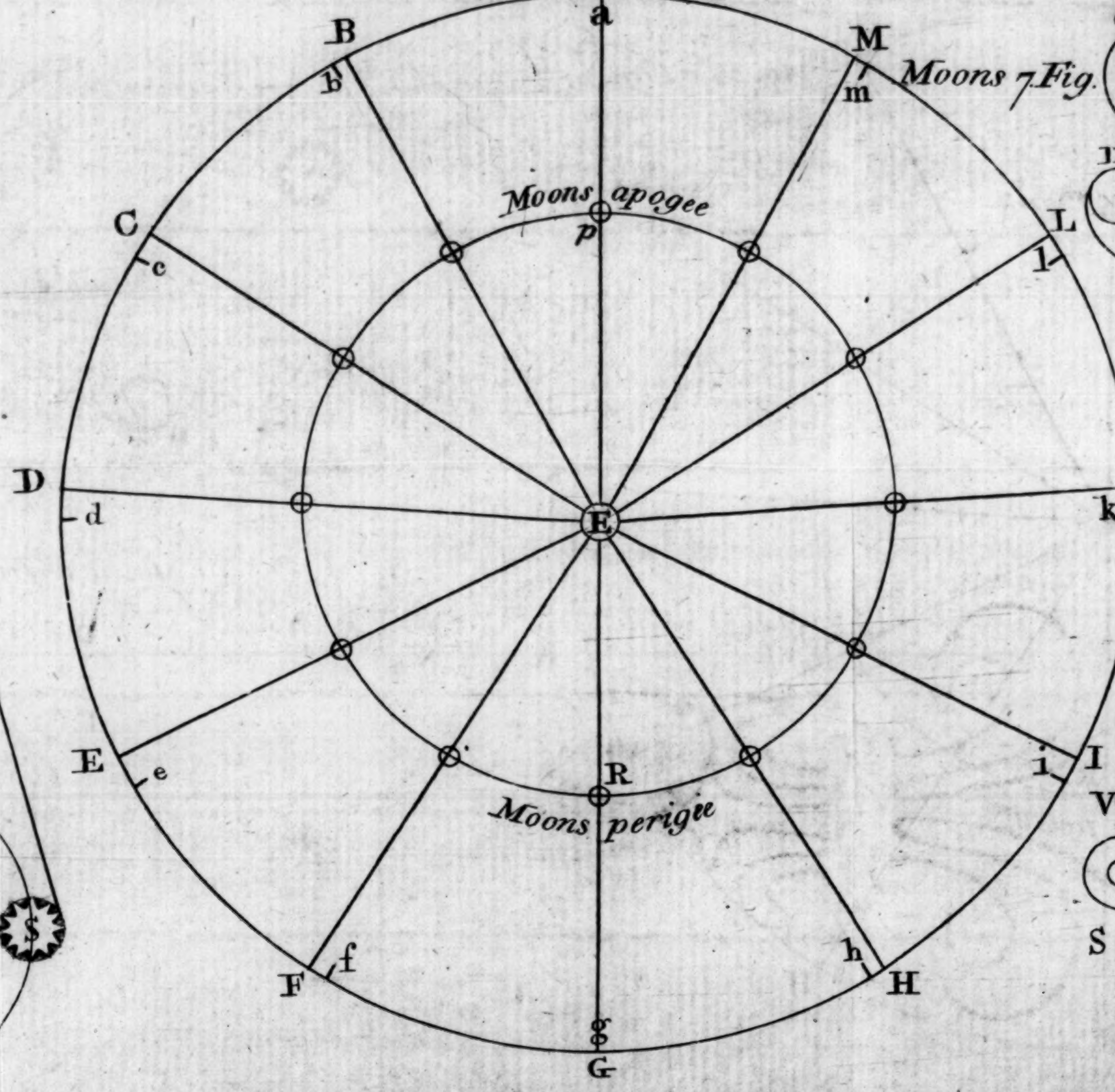
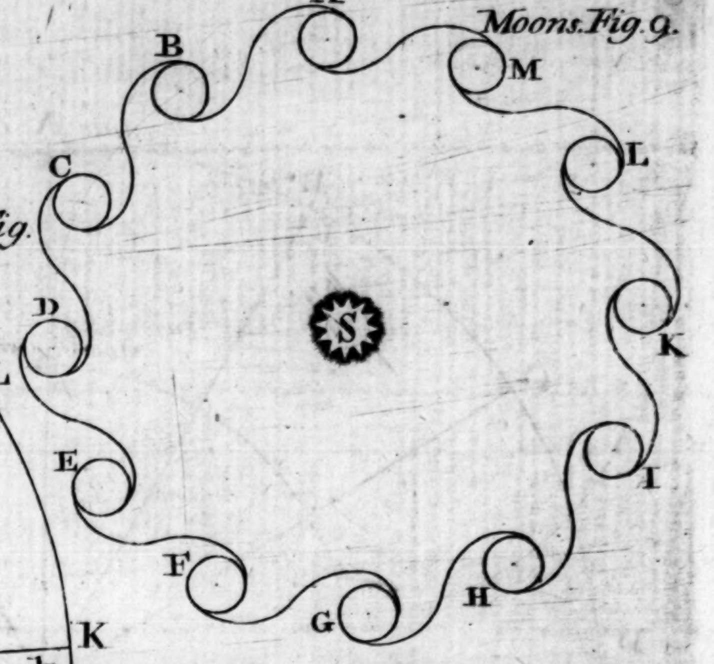


Fig. 2.

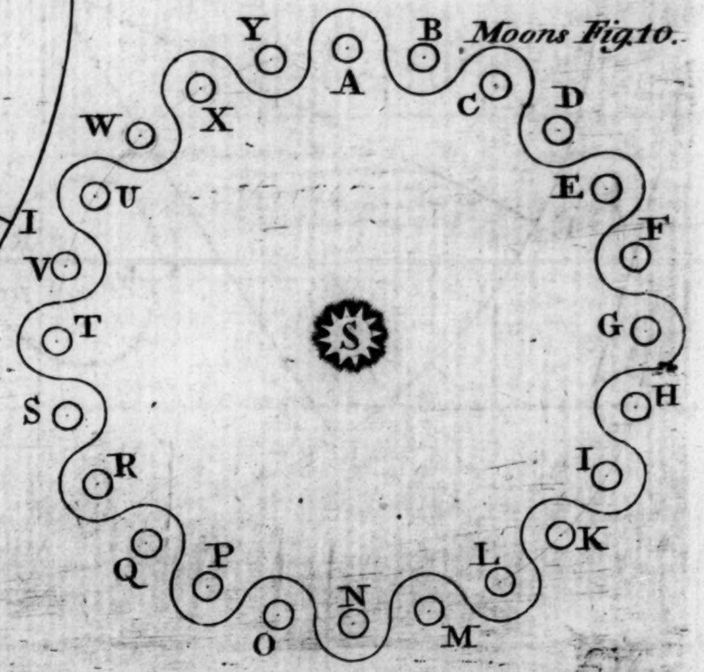




Moons 7 Fig.



Moons Fig. 9.



Moons Fig. 10.

And further, as to that notion, that a line or ray, drawn from the centre of the Sun to the centre of the Planet, which is carried about with an angular motion, does so move, that it describes or sweeps an Elliptic area, always proportional to the time, which Kepler calls the law of the Planets motion. But this notion of Keplers, and others, concerning the law of the Planets movement about the Sun, is not just and true, in fact; for the Planets motions, in their periods about the Sun, be not equable and uniform, yet the inequality of their motion is not so regulated, as to describe and sweep equal Elliptical areas in equal times. For when the course of a Planet, in its period about the Sun, is described according to the Astronomical Tables, in the Copernican scheme, we find, upon trial, that when the Planet is near to its Aphelion point, although it then moves slower in its Orbit, yet it then takes in and sweeps a greater area than it does when it comes near to the Perihelion. And, when the Planet is in the Perihelion, according to the Copernican scheme, although it moves quicker in its Orbit, yet it sweeps a less area than when it is in the Aphelion. So that this opinion, of the Planets sweeping equal areas, in equal times, is not founded on matter of fact, it being not just and exactly so.

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Of the very unequal Motion of the Moon in the Copernican scheme of Astronomy.

WE shall yet further shew, that the Planets do not move equable, and with the same veloci-

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ty all round in their periods, in any Aſtronomical ſcheme yet found out. For, according to the Copernican ſcheme, the Moon has a very unequal motion, as to the degree of velocity in her period about the Sun. For, according to this ſcheme of Aſtronomy, they ſuppoſe the Moon revolves about the Sun, along with the Earth, towards the eaſt, once a-year, and alſo circulates twelve times around the Earth, in eleven days leſs than a year.

Plate 22. the Moon's ſuppoſed Orbit about the Sun. Fig. 9.

Let then figure 9th, in this ſcheme, repreſent the order and manner of this courſe. For in this figure, the Sun at S, is ſuppoſed to be inmoveable in the centre; and the circle which is deſcribed about the Sun, ſhews the ſuppoſed annual courſe, or Orbit of the Earth about the Sun; and the twelve circles that are deſcribed about the Earth in its Orbit, ſhew that the Moon revolves twelve times about the Earth in ſomewhat leſs than a year's time. Now, it is evident from the inſpection of the figure, that the Moon muſt be ſometimes faſter, and at othertimes ſlower in her Motion.

Plate 22. the Moon's ſuppoſed Orbit about the Sun. Fig. 10.

For ſuppoſe, as in figure 10th, that the Moon, in attending on the Earth, and going around with it in its courſe about the Sun, ſets out as from A, and from A to B, and thence from B to C, from C to D, from D to E, from E to F, and ſo round to A again, it is manifeſt, that the Moon, when at A, muſt move faſter than when ſhe is at B, and at C than at D, and at E, than when ſhe is at F. For, agreeable to this ſuppoſed ſcheme, when the Moon is in that half of her Orbit about the Earth, as at A, ſhe muſt move faſter than the Earth does in the ſuppoſed Orbit that they both have about the Sun; and when ſhe is at B, in the other half of her Orbit ſhe muſt move ſlower

than the Earth. And when the moon is at C, ſhe moves again faſter, and at D ſhe moves ſlower than the Earth in their annual courſes. In the one caſe the Moon's motion is faſter than the Earth's; and in the other caſe, the Earth's motion is faſter than the Moon's, in her curve courſe about the Sun.

And as is the caſe of the Earth and Moon, in this ſuppoſed Orbit of theirs about the Sun, ſo alſo is the caſe of the Satellites of Jupiter and Saturn, in reſpect of their primary Planets; for they make very great curves in their general courſes, in their attending upon Jupiter and Saturn, around in the firmament of Heaven. For the four Satellites, that circulate about the body of Jupiter, they perform their circulations round him in different periods. That Satellite which is next to Jupiter, goes round him in 1 day 18 hours and one half; the ſecond, deſcribes his, in the ſpace of 3 days and 13 hours; the third, finiſhes his circulation in 7 days and 4 hours; and the fourth and outmoſt compleats his period about Jupiter, in the ſpace of 16 days 18 hours and a half.

And as for the five Satellites that turn round the body of Saturn, their periodical times are as followeth. The firſt and neareſt Satellite to Saturn, compleats his revolution in 1 day 21 hours and 19 minutes; the ſecond revolves about him in 2 days 17 hours and 40 minutes; the third finiſhes his revolution in 4 days 12 hours and 25 minutes; the fourth compleats his period in 15 days 22 hours and 41 minutes; and the fifth and outmoſt takes 79 days 7 hours and 48 minutes to finiſh his courſe about the body of Saturn. As for the reſpective diſtances of theſe Satellites, from the bodies of Jupiter and Saturn, we have given an account before.

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So these nine Satellites, though they have an apparent relative uniform motion about the bodies of Jupiter and Saturn, yet when considered, as circulating with their primary Planets about the body of the Sun, as in the Copernican scheme, or about the Earth, in the system that we embrace, their velocity is sometimes accelerated, and at other times retarded, in their circuit about in the ambient space.

After this description of the periodical time of these Satellites, in going round their primary Planets, it is most certain and evident to the intelligent reader, even without a figure drawn to represent it, that which ever way Jupiter and Saturn have their real course, either from west to east, as the Copernican scheme supposes; or from east to west, according to the Ptolemaic system, that these nine Satellites, must all describe different sorts of curves or loops, in their revolving about with their primary Planets. And with respect to their primaries, they move sometimes direct, at times they are stationary, and at other times they are retrograded in their course; so that they do not move with the same degree of velocity, but sometimes they are faster, and at other times they are slower in their motion, when they are considered, both as moving respectively about Jupiter and Saturn, and also in accompanying Jupiter and Saturn round about in their Orbits. This twofold modification of these Satellites motion, is the reason why they do not at all times move with the same velocity, in their curve lines or tracks, which they keep in the ambient space. And this inequality of their velocity will appear, in whatever point of space they are viewed from.

From what has been now described, of the inequa-

lity of the motion of theſe ten bodies in the Heavens; to wit, of the Moon and the nine Satellites of Jupiter and Saturn, a Copernican Aſtronomer needs not be ſurprized at the deſcription which we have given, and the diagrams made for exhibiting the Orbits and courſes of theſe five Planet-Stars, Saturn, Jupiter, Mars, Venus and Mercury, every day apparently and really moving about from eaſt to weſt, in the ambient ſpace. For if the Moon and the nine Satellites, theſe ten bodies in the Heavens, be under ſuch modifications and regulations in their motions, as that they move ſometimes direct, at times they are ſtationary, and at other times they are retrograde in their courſes; one while faſter, and another while ſlower in their motion, in the ambient ſpace, which appears when they are viewed from any point of ſpace whatever. And this will be obſerved, and really appear, whatever ſyſtem of Aſtronomy be embraced. Whether the courſe of the Heavens be ſuppoſed to move from weſt to eaſt, or from the eaſt towards the weſt. We ſay, ſince ten bodies in the firmament of Heaven are under ſuch modifications and regulations in their motions, as not to move always with the ſame velocity at all times alike; ſo alſo, may be the caſe with five.

As there is nothing that appears to be in the nature of any moving body, to prove that it is otherwiſe; therefore it can be no argument againſt the motion and circulation of Saturn, Jupiter, Mars, Venus and Mercury's diurnally circulating from the eaſt towards the weſt, in their different Orbits, becauſe that we ſee theſe Planets, in their motions, are not uniform with the other Stars in the firmament of the Heavens.

And we ſhall here mention an objection, which we have againſt the courſe of the Moon, as is repreſented

CHAP. XXVII. in the 9th and 10th figures above deſcribed, (for theſe diagrams were made upon the Copernican principles;) becauſe it would ſuppoſe the Moon to have her courſe in the Heavens from weſt to eaſt, and without her having a real motion from the eaſt to the weſt, which is according to ſenſible and viſible obſervation, and would give the Moon, which is the ſecond great light in the Heavens, a very curve and unequal motion, in her way around in the firmament of Heaven; beſides, as it unneceſſarily ſuppoſes the Earth to move about in the ambient ſpace, along with her, which appears to be but a human contrivance of ſome men, contrary to the due courſe of nature and order in the Heavens.

CHAP. XXVIII.

Of the Eclipſes of Jupiter's Satellites, demonſtrating whether Light be diffuſed inſtantaneouſly from the Sun or not.

THE Copernican Aſtronomers endeavour to prove the motion of the Earth about the Sun, and alſo the ſucceſſive motion of Light, that it takes ſome time to arrive from the Sun, or any diſtant object to us, by the Eclipſes of Jupiter's Satellites; that is, when any of theſe Satellites is Eclipſed, by paſſing through Jupiter's ſhadow. As this is a problem that requires conſideration, I ſhall give it a demonſtration in as plain a method as is poſſible.

By the Eclipſes of Jupiter's Satellites, we are able to give the ſolution of a problem, which is the moſt

intricate and curious in Natural Philoſophy, that is, whether Light be propagated to us in an inſtant, or if its motion be ſucceſſive, and takes ſome time in its way to us from the Sun, or any other diſtant object. The following demonſtrations ſhew us, that if the Earth were in motion about the Sun, Light would require ſome time in arriving to us from the Sun, or other diſtant objects. But if the Sun be in motion about the Earth, the following demonſtration ſheweth, that Light comes inſtantaneouſly from all diſtant objects to us.

But that Light proceeds to us inſtantaneouſly from any of the Heavenly Bodies to us, is manifeſtly certain. For if it were otherwiſe, when the Sun is in the Equator, we would not ſee him in the morning when he ariſes, till 8 $\frac{1}{4}$ minutes after ſix o'clock, and at night when he ſets, we would ſee him 8 $\frac{1}{4}$ minutes after ſix o'clock, whereas it is manifeſt, we ſee the Sun, when in the Equator, that he riſes and ſets at ſix o'clock; and we ſee the Sun in the morning, in that ſecond of time, that he arrivesat the Horizon, and we loſe ſight of him in that very inſtant that he dips below the Horizon. For as the Sun's movement in the Ecliptic, and his Anomaly is found, the Equation is very well known. For take the Sun's Equation, when in the Equator, he will appear in the morning, and diſappear in the evening equally near ſix, by a well regulated clock.

For if the Sun's ray of Light were darted from him through the air, like an arrow from a bow, and proceeded progreſſively, it would take ſome time in the morning, after he were really on the Horizon, before he could be ſeen. And the Sun's ray of Light would be as long ſeen in the evening after he were really dipt

CHAP. XXVIII. below the Horizon. Whereas, without loſs of time, we ſee the Sun in the morning in that very ſecond of time that he ariſes in the Horizon, and have no further benefit of any ſight of him in the evening, the ſpace of one ſecond of time, after he is ſet in the Horizon.

Therefore, ſince light or ſight of a luminous object, in the Firmament of Heaven, is inſtantaneous, the obſerving of the Eclipſes of Jupiter's Satellites 8 $\frac{1}{4}$ minutes ſooner in ſome parts of the Sun's Orbit than in others, muſt ariſe from the Sun's circulating about the Earth; and when darting his beams upon Jupiter, makes Jupiter's ſhadow ſometimes to fall forewards upon the Satellite, and ſometimes backwards upon it, and not the Earth circulating about the Sun, as it is demonſtrated by the two following figures, to be the cauſe why the Satellites are 8 $\frac{1}{4}$ minutes ſooner eclipſed in the one poſition than in the other; that is, when Jupiter is to the weſt of the Sun, and ſeen in the morning, the Satellite falls ſo much ſooner into the ſhadow of Jupiter; and when Jupiter is to the eaſt of the Sun, and ſeen in the evening, the Satellite falls ſo much latter in Jupiter's ſhadow, which ariſes from the different angles under which the Sun, Jupiter, and the Satellite, are ſeen from the Earth, and not from the ſlow progreſſive motion of light or ſight of a diſtant luminous object.

Plate 22. the Eclipſes of Jupiter's Satellites Fig. 1.

Therefore, Let figure 1ſt repreſent theſe Eclipſes according to the Copernican ſyſtem, where S is the Sun in the centre, and EE the earth in its Orbit, J Jupiter, and the two circles about him the orbits of two of his Satellites. This figure is placed to repreſent both the progreſſive motion of Light, and to ſhew that the Earth moves in an Orbit about the Sun. To

illustrate this progressive motion of Light, Let EE be the Earth in two different parts of its Orbit, whose distance from each other is 81 millions of miles, equal to the earth's supposed distance from the Sun, S, it is plain, if the motion of Light were instantaneous, the Satellite would appear to enter Jupiter's shadow at the same moment of time, to a spectator at the most distant E, as to another at the E next to Jupiter; but by many years observations, it has been found that the immersion of the Satellite into the shadow is seen 8 $\frac{1}{4}$ minutes sooner when the Earth is at E, next to Jupiter, than when he is at the other E most distant from him, which is near a semidiameter of the Earth's orbit. And as Light is 16 $\frac{1}{2}$ minutes in travelling across the Earth's orbit, it must be 8 $\frac{1}{4}$ minutes in coming from the Sun to us.

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Plate 22. the Eclipses of Jupiter's Satellites Fig. 2.

And also, Let figure 2d represent these Eclipses according to the Ptolemaic system of Astronomy, where E is the Earth in the centre, and SS the Sun in his orbit, J Jupiter, and the two circles about him the Orbits of two of his Satellites. This figure is so constructed, as to represent to us that light is instantaneous, and that the Sun moves in an Orbit about the Earth.

To illustrate this, Let SS be the Sun in two different parts of his Orbit, and the two black shadows on the backside of Jupiter, be the two shadows that are cast by Jupiter, when the Sun is in these two opposite points of his Orbit. It is evident, by observation, when looking at this figure, that when the Sun is at S, at the point of his Orbit towards the left hand, that Jupiter casts his shadow inclining towards the right side of the plate. And when this comes to be the situation of the Sun and Jupiter, a spectator at E, upon the Earth, of consequence, must see the Satel-

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lite fall into the ſhadow ſooner than when Jupiter caſts his ſhade the other way; becauſe the firſt ſhadow is ſo inclined as to meet the Satellite in its Orbit courſe, and the other ſhadow inclines backward the reverſe way, and ſo the Satellite is ſo much latter in falling into it. The caſe is much the ſame with reſpect to the Satellites falling behind Jupiter's body, and being Eclipſed by him. For when the Sun is at S, on the left-hand ſide of the figure, and to the eaſt of Jupiter, a ſpectator at E on the Earth ſees Jupiter inclining to the right hand meeting the Satellite in its courſe, and Eclipſing it ſooner. But when the Sun is at L, on the right ſide of the figure, and to the weſt of Jupiter, the Planet inclines ſo much back as to Eclipſe it latter. In this laſt ſituation, the Satellite falls behind Jupiter's body before it meet with the ſhadow. In the firſt of theſe two ſituations the Eclipſes will happen to be 8 minutes ſooner, and in the laſt, 8 minutes latter than the Tables point them out to be; becauſe theſe Aſtronomical Tables were made to deſcribe the mean time of theſe Satellites' Eclipſes.

And as to the time of theſe Eclipſes, both theſe figures repreſent them to happen preciſe at the ſame inſtant of time. For, as in figure 1ſt, the Earth is repreſented as moving from the Point P towards the point L; ſo alſo in figure 2d, the Sun is repreſented as moving on, or rather falling back upon Jupiter in his courſe, from the point S to the point L, which is juſt reciprocally the ſame. For the ſtraight lines LI, and LB, are parallel lines to each other.

Now, as to that queſtion, whether Light is progreſſive or inſtantaneous, the anſwer to it depends intirely on this, whether the Earth be in motion, or at reſt. For if the Earth be ſuppoſed to be in motion,

by that motion in its Orbit, it will ſometimes of the year be betwixt the Sun and Jupiter; and, at another time of the year, it will be in the moſt diſtant point of its Orbit from Jupiter. But as theſe two poſitions of the Earth cannot be compared together in this caſe, becauſe Jupiter is too near the Sun for ſome time, when in conjunction with him, that the Eclipſes of his Satellites cannot be ſeen. And theſe are moſt viſible when the Earth is at E, or E, as in figure 1ſt; and, by obſervation, it is found that the Eclipſes of Jupiter's Satellites are ſeen 8 $\frac{1}{4}$ minutes ſooner when the Earth is at E next to Jupiter, than they are when the Earth is at the other E that is moſt diſtant from Jupiter, which is as much as a ſemidiameter of the Earth's Orbit. This 8 minutes of difference in time, as to the Eclipſes of theſe Satellites, when the Earth is in theſe two different poſitions, would demonſtrate that Light comes from Jupiter to the Earth progreſſively, in that certain ſpecified time.

But if the Sun be in Motion about the Earth, he will at one time of the year be viewed and ſeen at an angle behind Jupiter, and to the eaſt of him; and at another time of the year, the Sun will be ſeen at an angle before Jupiter, and to the weſt of him. At the firſt of theſe views, the Eclipſe of the Satellites will be ſeen 8 minutes ſooner than according to the Tables; and at the other of the obſervations, they will be ſeen 8 minutes latter than the Tables predict them to be.

But this gives no evidence that the motion of light is progreſſive, and takes a definite time in coming from Jupiter to the Earth, but the contrary; and that the ſight of an object, at a very great diſtance in a pure medium, is inſtantaneous. For, according to figure 2d, and agreeable to the nature of things, it

Plate 22. Eclipſes of Jupiter's Satellites. Fig. 2.

cannot be conſidered, and properly underſtood otherwiſe. For when the Sun is at S, on the left-hand ſide of the figure, we have ſuch a view of the Sun, Jupiter and the Satellite, by an angle from the Earth, that Jupiter, or his ſhadow, meets the Satellite ſo much ſooner in its Orbit courſe. And when the Sun is at the right-hand ſide of the figure, and before Jupiter, the Planet, with its ſhadow, inclines ſo much to the left ſide, that by a Mathematical conſequence, the Satellite muſt be ſo much latter in being Eclipſed, and of emerging of it behind Jupiter or his ſhadow. All this accounts very well for the juſtneſs of the Aſtronomical obſervations, and their accuracy in finding theſe Eclipſes to be ſometimes 8 $\frac{1}{4}$ minutes ſooner, and at other times 8 $\frac{1}{4}$ minutes latter, than the Tables predict them to be.

And this, at the ſame time, harmoniſes with that principle, that light, or ſight of a diſtant luminous object, is inſtantaneous. And that when we open our eyes and when we look up to the Sun or a ſtar, we ſee them in that very ſecond of time that our eyes are fixed on them. As to the proof of the Sun's motion, and the Earth's being at reſt, it depends upon ſeveral other demonſtrations, which we have formerly given, as well as by this.

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The Scripture Account of the Motion of the Sun, Moon, and other Celeſtial Bodies in the Firmament of Heaven.

THE firſt Scripture that we here mention is, Pſalms xix. and verſes 1, 2, 3, 4, 5, and 6.

" The Heavens declare the glory of God: and the
" Firmament ſheweth his handy work. Day unto day
" uttereth ſpeech, and night unto night ſheweth
" knowledge. There is no ſpeech, nor language,
" where their voice is not heard. Their line is gone out
" through all the Earth, and their words to the end
" of the world: in them hath he ſet a tabernacle for
" the Sun, Which is as a bridegroom coming out of his
" chamber, and rejoiceth as a ſtrong man to run a
" race. His going forth is from the end of the Heaven,
" and his circuit unto the ends of it: and there is
" nothing hid from the heat thereof." The deſign of this Pſalm is to adore and magnify the name of God, for the diſcovery of his wiſdom, and power, and goodneſs, both by his great and glorious works of creation and providence, and eſpecially by his word in the Holy Scriptures.

In the firſt part of this Pſalm that we have now before us, and under our conſideration, the holy Pſalmiſt treats in a moſt elegant manner of the Being and Perfections of God, being made manifeſt in a moſt conſpicuous manner in theſe viſible Heavens, which we behold, which are ſo vaſt and ſpacious, and richly adorned with Stars, ſo various and admirable in their courſe, and different in their ſtations, and ſo uſeful and powerful in their influences. The Heavens are an univerſal and admirable teacher, that they can ſpeak to all people under them, and be clearly underſtood by all. That wiſe and learned Heathen, Tully, ſaith, " That no nation or people is ſo barba-
" rous and ſottiſh, as when they look up to the Hea-
" vens not to perceive that there is a God, or to ima-
" gine that they are the effect of blind chance, which
" are made with ſo much wonderful art and wiſ-

" dom, that it requires extraordinary art to under- " ſtand their excellent orders and courſe." Verſe 4th, " In them," that is in the Firmament, " hath he " ſet a Tabernacle for the Sun," which is a moveable habitation, and therefore fitly applied to the Sun, which is here ſaid, in the 5th and 6th verſes, to be in conſtant and perpetual motion. Verſe 5th, " Which is " as a bridegroom coming out of his chamber, and " rejoiceth as a ſtrong man to run a race." The beauty of the Sun is here elegantly compared to a well-adorned bridegroom, with apparel upon his wedding-day; and the Sun's ariſing in the eaſt to a bridegroom's coming out of his chamber, and to a man of great ſtrength, that with alacrity and chearfulneſs ſets out in a race upon a buſineſs of great importance. The Sun's ſudden bolting up in our Horizon in the morning, his radiant beams and glorious light, his ſwift and conſtant motion over our Hemiſphere through the day, beautifully illuſtrate this compariſon.

Verſe 6th, " His going forth is from the end of " the Heaven, and his circuit unto the ends of it." His courſe is conſtant from eaſt to weſt, while above our Hemiſphere, and thence to eaſt again, when he is below it. The Sun's going forth from the end of Heaven, plainly ſhews to us that he moves; and his circuit unto the ends of it, holds forth that he turns round the Earth in his courſe once a day. We obſerve, that when the Sun is here compared to a bridegroom coming out of his chamber, and to a ſtrong man that rejoiceth to run a race, he is not repreſented in the words as paſſive, but as active in it, as is manifeſt to all men that duly conſider this text of Scripture; theſe words coming, rejoicing, and run-

ning in a race, are all active and loculative terms, and represent the Sun to be in an active and moving situation. CHAP. XXIX.

And when the Pſalmiſt deſcribes here, "that the "Sun's going forth is from the end of Heaven, and "his circuit unto the ends of it," this is not figuratively expreſt, nor any ſimilitude brought in, but literally and amply deſcribing and ſaying, that the Sun moves in his circuit, from the eaſtern part of our Hemiſphere to the weſtern part of it, and from that again to the eaſt.

The ſecond Scripture that we ſhall here make uſe of, for proving the Sun's motion is Eccleſiaſtes, 1ſt chapter 4th and 5th verſes, "One generation paſſeth "away, and another generation cometh: but the "Earth abideth for ever. The Sun alſo ariſeth, and "the Sun goeth down, and haſteth to the place "where he aroſe."

The inſpired Penman of this book, was a preacher and king over Iſrael in Jeruſalem, and in it he treats largely upon the vanity of all ſublunary things, not that he eſteemed them vain in themſelves, for ſo they are God's creatures, and therefore good and really uſeful in their kinds, but in reference to men, and to that happineſs which men ſeek, and confidently expect in them.

Verſe 4th, "One generation paſſeth away, and "another generation cometh: but the Earth abideth "for ever." All things are here ſaid to be in a moving, fluctuating and changing ſituation, ſo men alſo: men continue but for one age, but the Earth abideth for ever, that is, through all the ſucceeding generations of men.

And verſe 5th, "The Sun alſo ariſeth, and the

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"Sun goeth down, and hasteth to the place whence "he arose." The Sun is in perpetual motion, sometimes arising, and sometimes setting, and then arising again; and so constantly repeating his courses in all succeeding days, years and ages. And the like he observes concerning the winds and rivers, as he observes in the following 6th and 7th verses.

We observe here, that the inspired Penman of this book speaks here in this chapter both of the Earth and of the Sun; of the Earth in the end of the 4th verse, "but the Earth abideth for ever"; and of the Sun in the 5th verse, "The Sun ariseth and the Sun "goeth down, and hasteth to the place where he "arose." The Scripture after speaking of the Earth's abiding, proceeds and gives us a description of the Sun's motion, and in the most plain and ample terms. When the Sun or any other object whatsoever is said to arise, and when it is said to go down, and also when it is said to haste in its way to a certain place, are all words and expressions that represent and shew forth, that *that* object is in a moving situation; and no words can be conceived that will more fully declare it to be so.

The third Scripture that witnesseth the same thing, is Psalms civ. and the 19, 20, 22, and 23 verses. "He appointeth the Moon for seasons; the Sun "knoweth his going down. Thou makest darkness, "and it is night: wherein all the beasts of the forest "do creep forth. The Sun ariseth, they gather them-"selves together, and lay them down in their dens. "Man goeth forth to his work, and to his labour un-"til the evening." As the Psalmist, throughout the whole of this Psalm, treats of and celebrates the wonderful and gracious works of God to all man-

kind, in the creation of this viſible world, and in the wiſe and powerful diſpoſition of all things therein to man's uſe and comfort.

So in theſe verſes of the Pſalm we have now before us, he deſcribes the manifold uſe of the Sun and Moon to mankind on the Earth; he appointeth the Moon for ſeaſons, to meaſure and diſtinguiſh the times, both months, and amongſt nations years alſo; as alſo the ſeaſons of divers events in nature, as the ebbing and flowing of the Sea, and of other ſeaſons for ſacred and civil affairs, which were commonly regulated by the Moon, not only among the Jews, but among Heathens alſo. "And the Sun knoweth "his going down," to wit, the time and place in which he is to ſet, every day of the year, which though varied from day to day, yet he ſo regularly and exactly obſerves, as if he had the underſtanding of a man or angel, to guide him in obeying the laws of his Creator. What is here expreſt concerning his ſetting, is neceſſarily ſuppoſed concerning his riſing alſo; for he mentions only his ſetting as moſt agreeable to the context, becauſe that did uſher in the riſing of the Moon, of which he now ſpeaks in the next words, verſe 20, "Thou makeſt darkneſs, and "it is night;" the darkneſs ſucceeds the light by virtue of the divine decree, and eſtabliſhed orders: ſo by this viciſſitude of day and night, God hath wiſely and mercifully provided, both for men that they may follow their days labours without danger from wild beaſts, and for the beaſts that they may procure ſubſiſtence. Verſe 22, "The Sun ariſeth, "they gather themſelves together, and lay them "down in their dens;" as the Sun knows the time of his going down the beginning of the other

night, ſo he knoweth the ſet and appointed time of his urpiſing on the next day.

We obſerve here, that in the 19th verſe of this Pſalm, the Pſalmiſt ſpeaks both of the Moon and of the Sun. And firſt of the Moon, that the Lord appointed the Moon for ſeaſons. And as there was not ever any perſon that I have yet heard of, that doubted of the motion of the Moon, but that ſhe circulates round the Earth; ſo he ſayeth in the laſt part of the verſe, "That the Sun knoweth his going "down;" theſe words are delivered in the moſt active ſenſe, and the whole verſe runs more clearly for the motion of the Sun, than it doth for that of the Moon. The Sun's going down expreſſes his active motion; and when it is ſaid that he knoweth the time of his going down, this aſcribes to the Sun both active circulation and exactneſs in his movement, both as to the place where, and the time when he goeth down, and when he ariſeth.

A fourth Scripture that proveth the movement of the Sun, is Judges 5th chapter and verſe 31ſt, "Let "all thine enemies periſh, O Lord; but let them that "love him be as the Sun when he goeth forth in his "might." The propheteſs Deborah, in this Scripture, ſheweth and holdeth forth the motion of the Sun, and the irreſiſtible force and power by which he ariſeth and goeth on in his courſe, which he doth with great might, even as a ſtrong man that runneth a race, and ſo no creature can ſtop or hinder him in his going forth. And it is to this irreſiſtible might of the Sun, in his going forth in his courſe, that the inſpired Propheteſs compares thoſe that love God. Even ſo let them not be withſtood—The Sun goeth forth in his might and cannot be withheld; ſo let them be.

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Of the Motion of the Stars in the Firmament.

As we have the motion and circulation of the Sun and Moon plainly and clearly deſcribed in Scripture, ſo alſo of the Stars. In the 38th chapter of the book of Job and 32d verſe, the Lord puts this queſtion to Job, "Canſt thou bring forth Mazzaroth in his ſeaſon, "or guide Arcturus with his ſons?" What this conſtellation Mazzaroth is, whether it be the twelve Signs of the Zodiac, or ſome other particular conſtellation is not yet agreed; but it is ſufficient to our purpoſe, that the query that was made to Job, "Canſt "thou bring forth Mazzaroth in his ſeaſon?" which was impoſſible for Job and all mortal men to do, ſhews us that Mazzaroth doth come forth when he ariſeth and appeareth in our Hemiſphere. And among the many queſtions that were put to Job in this chapter, of a particular nature, this is one, of bringing forth this conſtellation. And as none of the demands that the Lord made upon Job, were of ſuch a nature but what he himſelf doth by his all over-ruling Providence, bringing forth this conſtellation, together with all other conſtellations in the Heavens, and maketh them circulate around the Earth in their courſes. And in the laſt part of this 32d verſe, the Lord makes another demand upon Job, "Or canſt "thou guide Arcturus with his ſons?" Arcturus is another conſtellation near that called the Bear, which ariſeth to us in September. This queſtion "Canſt "thou guide Arcturus with his Sons?" doth import, Canſt thou give them eſtabliſhed laws, as to their ſtation, their order and motion, and their powerful in-

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Another Scripture to this purpoſe, is in the Song of Deborah the Propheteſs, after the battle with Jabin king of Canaan, and the diſcomfiting of Siſera and his hoſt, when ſhe was there illuſtrating that notable victory which the Lord gave to the Iſraelites over their enemies in battle. Deborah as a Propheteſs, and under divine inſpiration, deſcribes how that the influences of the Heavens and the Stars in their courſes, aſſiſted them in obtaining the victory; as we have it in Judges, v. chapter and 20th verſe, "They "fought from Heaven, the Stars in their courſes "fought againſt Siſera." They from Heaven, or the heavenly hoſts fought by thunder, lightning and hailſtones, as we may compare this with Joſhua, x. chapter and 11th verſe, together with 1 Samuel vii. chapter and 10th verſe, and as it is in the laſt part of this 20th verſe, "The Stars in their courſes "fought againſt Siſera;" or the Stars from their paths and higher ſtations, as ſoldiers fight in their ranks and marches, when purſuing after a flying army; ſo did theſe, and with advantage, as thoſe armies do when they fight from the higher ground.

We ſee from this Scripture, that the Propheteſs Deborah aſcribes motion to the Stars, when ſhe deſcribes as fighting in their courſes; as the word courſe is a term, which properly ſignifies local motion. But I need not multiply quotations to prove the motion of the Sun, Moon and Stars, for many places of Scripture poſitively affirm it, or in others it may be implied from them; and no paſſage of Scripture that I know of, ſpeaks of the Sun, Moon and Stars being at reſt, except when they were ſtopt by miracle.

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The Scripture Account of the Sun and Moon's ſtanding ſtill in the Firmament of Heaven, in a miraculous manner.

WE have the Sun and Moon's ſtanding ſtill very particularly and plainly related to us in the Book of Joſhua, chapter x. the 12, 13 and 14 verſes, " Then ſpake Joſhua to the Lord in the day " when the Lord delivered up the Amorites before the " children of Iſrael, and he ſaid in the ſight of Iſrael, " Sun, ſtand thou ſtill upon Gibeon, and thou Moon, " in the valley of Ajalon. And the Sun ſtood ſtill, " and the Moon ſtayed, until the people had avenged " themſelves upon their enemies. Is not this written " in the Book of Jaſher? ſo the Sun ſtood ſtill in the " midſt of Heaven, and haſted not to go down about " a whole day. And there was no day like that, " before it or after it, that the Lord hearkened " to the voice of a man: for the Lord fought for " Iſrael.

Joſhua being moved out of his zeal to deſtroy God's enemies, and being directed to it by God's Holy Spirit moving him in it, and he receiving a gracious anſwer, and being filled with holy confidence of the ſucceſs, he ſpeaks in the preſence and audience of Iſrael, that the people might be witneſſes of it. " Sun, ſtand thou ſtill upon Gibeon," that is over and above Gibeon, in that place and ſituation in which it now ſtands and looks upon Gibeon: let it not go down lower out of the ſight of Gibeon. It may ſeem that this

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was in the afternoon, and the Sun beginning to decline, and Joſhua perceiving that his work was great and long, and his time but ſhort, he then begs of God the lengthening out of the day, and that the Sun and Moon might ſtop their courſes, and keep the place in which they were at preſent. And what Joſhua ſaid to the Sun, he ſaid alſo to the Moon, "And thou Moon "in the valley of Ajalon," or ſtay over and above the valley of Ajalon. It is probable, and very likely that the ſituation of the Sun and Moon at this time, was ſuch, that the Sun appeared to be above Gibeon in his courſe, and the Moon then above ſome part of the valley of Ajalon, which might be well known to Joſhua, though then Sun-light when he ſpoke theſe words in the ſight of Iſrael. Joſhua begs the Moon to ſtand ſtill as well as the Sun; not that he needed the Moon's light when he had the Sun's, but it was fit either that both Sun and Moon ſhould go, or that both ſhould ſtand ſtill, to prevent diſorder and confuſion in the Heavenly Bodies.

But if it ſhall be objected againſt what is above ſaid, that Joſhua ſpoke very improperly and indiſtinctly, and ſeemed to be unacquainted with the true principles of Philoſophy and Aſtronomy, in his looking to the wrong object, and ſpeaking to a different ſubject for the operation that he ſhould have done. A Philoſopher would not have looked to the Sun in this caſe as his object, becauſe it was ſtanding ſtill and immoveable already, but have ſpoke to the Earth as the ſubject of operation, and ſaid, "Earth ſtand thou "ſtill, ceaſe from turning upon thine axis, in thy di-"urnal motion, and ſtop thy career in thine annual "motion and circulation;" and alſo to the Moon, and have ſaid, "Thou Moon, the Earth's near companion

"and mover with it in the ambient ſpace, ſtand thou "ſtill likewiſe, over and above the valley of Ajalon, "and abide by the Earth ſtopt in its courſe."

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But Joſhua had no need for the direction of any human Philoſophers or Aſtronomers in that caſe, he was ſpeaking to God in this matter, and now ſpeaking under the immediate aſſiſtance and direction of God's moſt wiſe and knowing Spirit, and now endowed with the faith of miracles, and was thereby directed both to look to the proper objects, and ſpeak to the only ſubjects of operation. Therefore Joſhua at the head of his army, and in the ſight of the Iſraelites who were there along with him, he ſaid, "Sun ſtand thou ſtill," that is, ſtop a little in thy circular courſe around the Earth, and keep thy ſtation where thou art at preſent to give us light, till I and the army under my command, as we have now a divine commiſſion for it to avenge the Lord on his enemies, theſe Canaanites whom he hath devoted to deſtruction.

Verſe 13, "And the Sun ſtood ſtill, and the Moon "ſtayed, until the people had avenged themſelves "on their enemies. Is not this written in the book "of Jaſher? ſo the Sun ſtood ſtill in the midſt of "Heaven, and haſted not to go down about a whole "day." And the Sun ſtood ſtill, was ſilent, and ceaſed from his motion in going down, and the Moon ſtayed until the people had avenged themſelves on their enemies. As the Sun ſtood ſtill in the laſt clauſe of the verſe, ſo the Moon ſtayed as we have it in this, until the people had avenged themſelves on their enemies. This is given as the reaſon of this notable miracle, that the people might have the neceſſary required time to compleat the victory of that day, and alſo for ſtrengthening of their faith,

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that the Lord was on their side, and fought for them.

This remarkable and extraordinary event was also recorded in the book of that noted and upright historian Jasher, whose book was written and published before Joshua wrote this, and so is fitly mentioned here, but the works of this historian, not being canonical, were long since lost through the carnage and confusion of times. "So the Sun stood still in the "midst of Heaven, and hasted not to go down about "a whole day." These remarkable words of Joshua, being spoke after the Sun had past the Meridian, and was then beginning to decline in his course; yet at this time he was in a high situation in the Firmament, and not near his setting in the western Horizon. And this most singular stopping and retarding of the Sun in his circular motion continued for the space of a whole day, which would make this eventual and miraculous occurrence evidently discernible, and plainly to be observed by all the inhabitants of the world. And as the inspired Author of this book, wrote this part of the Scriptures some considerable time after this glorious and remarkable event was past, he says, "That there was no day like that before it or after "it, that the Lord hearkened unto the voice of a man." And even since the book of Joshua was wrote, we have no account in Scripture of any other day like this, but in Hezekiah's time, which was remarkable like this, in some respects. Nor is there found in any human historian, that can be depended upon, any relation of such like day. This was a most singular aid and assistance that the Lord gave to his people, that he stopt the course of these Luminaries in the Heavens, for their benefit and advantage.

We have the same reason to believe the truth of

this miracle that the Lord wrought at the desire of his servant Joshua, as we have for believing the truth of those miracles that the Lord wrought by the ministry of his servant Moses, or any other miracle that we read of in Scripture, when the ordinary laws of Nature were reversed, and any of the elements or bodies were stopt, and put out of their natural course.

We have observed above, that it was not the Earth, but the Sun and Moon on which this miraculous operation was wrought. For Joshua was permitted to direct his speech, first to the Lord, and then to the Sun, "Stand thou still upon Gibeon." The Sun's standing still in his station, and not hastening to go down in his course, are such evident testimonies, that the Sun was the subject on which this miracle was wrought, according to the ordinary meaning of words, that they cannot be understood in terms otherwise. Another Scripture we have is in the book of the Prophet Habakkuk, chapter iii. and 11. verse. "The "Sun and Moon stood still in their habitation: at the "light of thine arrows they went, and at the shining of "thy glittering spear." This hath a manifest relation to that wonderful work of the Lord, when he caused the Sun and Moon to stand still in the sight of Israel, when Joshua and his men were in pursuit of their enemies.

We may also take in here the ix. chapter of the book of Job and 7. verse, "Which commandeth the "Sun, and it riseth not: and sealeth up the Stars." We must acknowledge that this discourse of Job is to be understood poetically; but he speaks here either of what God can do, (for to him all things are possible) or of what he actually doth, and that either most ordinarily, and so he gives laws to the Sun, that it

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should not rise, but at such times, and to such places, and in such manner as he hath appointed, as that it shall rise constantly at its set time, and never disorderly. The Sun is always under the command of God in his ordinary revolutions, in his risings and settings; or secondly, what God doth extraordinary, for of such he treats also in this place. As when he causeth some extraordinary darkness, or dark season, "Wherein "the morning is made darkness, and he maketh the "day dark with night," as the phrase is, as it is said in several places of the book of the prophet Amos. Or so it may note some miraculous stop given to the Sun for a small season, as that in Joshua's time; and also when the Sun returned ten degrees backward in the time of Hezekiah's sickness. At these times the Sun did not rise to the inhabitants of the opposite parts of the Earth (to where he then was) according to his ordinary time, but was so much longer in doing of it.

The Scripture Account of the Sun's returning backwards ten degrees.

Second book of Kings the xx. chapter the 8, 9, 10, 11, verses, "And Hezekiah said unto Isaiah, What "shall be the sign that the Lord will heal me, and that "I shall go up into the house of the Lord the third day? "And Isaiah said, This sign shalt thou have of the Lord, "that the Lord will do the thing that he hath spoken: "shall the shadow go forward ten degrees, or go back "ten degrees? And Hezekiah answered, It is a light "thing for the shadow to go down ten degrees: nay, "but let the shadow return backward ten degrees. "And Isaiah the prophet cried unto the Lord, and he

“ brought the ſhadow ten degrees backward, by which “ it had gone down in the dial of Ahaz.” This was indeed a very remarkable and notable miracle that the Lord was pleaſed to work at the earneſt deſire and fervent prayer of his ſervant the prophet Iſaiah, for ſtrengthening of the faith of his ſervant the good king Hezekiah, which otherwiſe might be ſhaken by the greatneſs of his danger, and the impreſſion on his mind ſtill remaining that he was to die, and not to live, by a meſſage a little before brought to him by the prophet Iſaiah. This miracle was not only obſerved at Jeruſalem and by the inhabitants of that country, but alſo at Chaldea a country in the eaſt. For the Princes of Babylon ſent ambaſſadors to him, to enquire of the wonder that was done in the land, who having underſtood that it was done for Hezekiah’s ſake, ſent to inquire of the truth and manner of it. As to the ſpace which the Sun returned back, it was ten degrees; but whether theſe degrees were according to our method of dividing a circle into 360 parts; and if ſo he returned backward forty minutes, or two third parts of an hour; or if theſe ten degrees were reckoned from the degrees or lines deſcribed on the dial that ſtood either in the royal garden, or on the wall of the King’s palace. If it was in this caſe, the return poſſibly would be more, but which of the two it was, is not ſo material for us to know; it was ſtill ſo much as that it was clearly obſervable to all the ſpectators. But that this return in the ſhadow was inſtantaneous, is not ſaid; I ſhould rather incline to think that it was done progreſſively, as in that caſe it could be the more deliberately obſerved.

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But if ſome people ſhould think to avail themſelves from this deſcription in the book of Kings, that it

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is only said here that the shadow returned ten degrees backward, and that this might have happened from the Earth's turning about on its axis to the west, and returning backward so far in its annual course, as they are pleased to call it, as well as from the Sun's returning backwards.

Which of the two it was, whether the Earth or the Sun returned backward in his course, for our final determination in this matter, we shall have recourse to the prophet Isaiah, a man that was dictated by the Spirit of God, when he wrote this part of the Scriptures, and on whose determination we are to rest, as being most safe and free from danger; Isaiah, xxxviii. chapter, and the 4, 5, 6, 7, and 8, verses, "Then came "the word of the Lord to Isaiah, saying, Go and say "to Hezekiah, Thus saith the Lord, the God of David thy father, I have heard thy prayer, I have seen "thy tears: behold, I will add unto thy days fifteen "years. And I will deliver thee, and this city, out of the "hand of the king of Assyria: and I will defend this city. "And this shall be a sign unto thee from the Lord, "that the Lord will do this thing that he hath spoken: "Behold, I will bring again the shadow of the degrees which is gone down in the Sun-dial of Ahaz "ten degrees backward. So the Sun returned ten "degrees, by which degrees it was gone down."

This is a history of the same thing that we have related in the second book of Kings, and xx. chapter, concerning the sickness of king Hezekiah, and the miracle that was wrought at his recovery; and these words of the prophet Isaiah are almost verbatim with those of the book of Kings, with this amplification and definition, "So the Sun returned ten degrees, "by which degrees it was gone down." As the

ſubject of the motion, or the body that moved backward, is undefined in the book of Kings, this prophet deſcribes that to us here in the context before us, in as conciſe and ample terms as words can make it. For, ſays he, "the Sun returned ten degrees;" and then again expreſſes it by way of reduplication, "by which "degrees it was gone down;" ſo the words of the Prophet here, are both in themſelves evidently clear, and are agreeable to the analogy of other Scriptures that ſpeak of the Sun's motion.

Now it muſt be granted that the Spirit of God who knows all things, and that when he dictated to the Penmen of the Holy Scriptures, he knew whether the Earth or the Sun was in actual motion; and that the Penmen of the Scriptures wrote by the direction and inſpiration of the Holy Spirit, when they ſeverally, and each one of them wrote their part of the Scripture; both theſe muſt be granted, without embracing the principles of manifeſt Deiſm.

CHAP. XXXI.

The Scripture Account of the Immoveability of the Earth.

IN the xxxviii. chapter of the book of Job, the 1, 2, 4, and 6th verſes taken together; "The Lord "anſwered out of the whirlwind, and ſaid, Who is "this that darkeneth counſel without knowledge? "Where waſt thou when I laid the foundations of the "Earth? declare, if thou haſt underſtanding. Whereupon are the foundations thereof faſtened? or who "laid the corner-ſtone thereof?" This paſſage of Scripture is ſo much to our purpoſe of the Earth's

CHAP. XXXI. being immoveable, that very little needs to be ſaid upon it. The Lord himſelf comes in to ſpeak, and in a moſt majeſtic manner, holding forth his own ſovereignty in making the world, and ordering and governing it, and all things therein, and particularly his infinite wiſdom and power in laying the foundations of the Earth. This Earth, which is the foundation or lower part of the whole world, and ſettled it as firm and ſtedfaſt upon its own centre, as if it had been built upon the ſureſt foundations.

Then again he moves this queſtion to Job, " Who " hath laid the meaſures thereof, if thou knoweſt? " Whereupon are the foundations thereof faſtened?" This ſtrong and durable building hath no foundation but in God's power and word, which marvelloully eſtabliſhed it upon itſelf. This queſtion, " Whereupon " are the foundations thereof faſtened?" holds forth to us, that God by his providence and government of all created things, not only keeps the particular atoms and ſeveral parts of the Earth together in compact and unity, but alſo upholds and keeps it ſtedfaſt and immoveable in the centre of the ambient ſpace.

But paſſing by many paſſages of Scripture, where the Earth's immoveability is either implied, or fully expreſſed, I ſhall mention another very remarkable portion of Scripture, in the civ. Pſalm and 5th verſe, " Who laid the foundations of the Earth, that it " ſhould not be removed for ever." This Pſalm treats and celebrates the wonderful and gracious works of God to all mankind, in the creation of this viſible world, and in the wiſe and powerful diſpoſition of all things therein for man's uſe and comfort; and in this 5th verſe, he treats in particular of the

creation and preſervation of the Earth, that it "ſhould "not be removed for ever." By this we underſtand, that God hath founded or eſtabliſhed the Earth upon its own baſis or foundation, upon itſelf, or its own weight, whereby it ſtands as faſt and unmoveable as if it were built upon the ſtrongeſt foundations imaginable, and that it ſhall not be removed out of its proper place, which is the loweſt part of the world; "for ever", that is as long as the world continues. CHAP. XXXI.

In the words of the holy Pſalmiſt here, who was a man under divine inſpiration, and in that reſpect could not be miſtaken, neither could he intend to miſlead others, when he ſays, that "the Lord laid the "foundations of the Earth, that it ſhould not be remo- "ved for ever." Every word here is expreſs and ſignificant, ſhewing forth the reſt and immoveability of the Earth. Theſe words and terms; being *laid*, being *founded*, and *not to be removed for ever*, are as expreſs and expreſſive as words can be, to ſignify and hold forth the ſtableneſs and reſt of the Earth.

Again, if it ſhall be objected here, that the Scripture expreſſions which contradict the Earth's being in motion, and announce its being at reſt, were never intended to inſtruct us in Philoſophy or Aſtronomy, and therefore on theſe ſubjects, expreſſions are not always to be taken in the ſtricteſt ſenſe, but for the moſt part as accommodated to the common apprehenſions of mankind.

In anſwer to this, it is neceſſary in ſcience this ſhould be known, that the Earth is at reſt, and that the Heavenly Bodies move about it in the Firmament above, and ſhews us the harmony and agreement that there is between the word of God, and his works. And the Scriptures inſtead of being accommodated to

CHAP. XXXI. the common apprehensions of mankind, where their apprehensions were wrong founded, they contradict all such apprehensions and conceptions of mankind.

CHAP. XXXII.

Of the Firmament of Heaven, and whether there is Matter in it or not.

WE come to treat of the general Fabric and Firmament of the material Heavens, within whose circumference all those motions of material things are contained, whether of the Sun, Moon, and Stars, or ethereal meteors in the higher regions of the Heavens, or these in the Firmament of the Air, and lower region of Heaven; such as fiery meteors, winds, clouds, rains, snow, and hail, mist, and dew; and these on the surface of the Earth and Sea, as earthquakes, exhalations, fountains, streams, and evolutions in the ebbing and flowing of the Sea.

And when we come to treat of the Firmament of Heaven, or the ethereal and celestial part of the Material system, two things are to be considered; viz. its nature and its fixedness. And first, as to the nature of this Heaven, these famous questions present themselves agitated by the disputes of Philosophers for many ages, Whether there is matter in Heaven or not? Some positively affirming there is matter in Heaven, and others denying it, and averring that there is not. Those who affirm that there is matter in Heaven, say, wherever there is quantity and figure, there must needs be matter; for quantity im-

mediately follows the nature of matter, and cannot be in any thing without it. Wherefore, since we see that the Heaven hath quantity, is of a certain figure, and determinate magnitude, we must needs acknowledge that it hath matter in it. And the Cartesians say yet still further, that the Heaven is distinguished into divers orbs and contiguous spheres, or vortices of matter; that all turn about certain centrical points. And there also other modern Philosophers and Astronomers, which aver that there is nothing in the pure expanse of the Heaven but light.

We shall not here repeat what is brought to prove the grounds of their opinion, that are either on the one side of this question, or that are on the other; but as much as is possible, when on our enquiry on this subject, as to the ethereal nature, substance, and essence of the pure expanse of the Heavens, to avoid extremes, both on the one hand and on the other. And we are of opinion, that the pure expanse of the Heavens is not filled and occupied with a system of particles of matter, or a system of liquid air, of any considerable density, and of itself to move, or even as a medium, to make any sensible resistance unto the Sun, Moon, and Stars, or Comets in their motions therein. Neither are we of opinion, that the space above the Earth's atmosphere and region of Air, or the Firmament in which these heavenly bodies move, is perfectly and entirely a void or vacuum, and has no being or existence, and may be said that it is nothing.

We have before observed, that the bodily senses, governed by reason, and corroborated by divine revelation, is the only certain criterion for coming to the knowledge of what can be known concerning the order and situation of all the visible bodies of the u-

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niverse. But as to the subject now under our consideration, the organs of the senses can afford no assistance to our reason in it, but in a negative manner. Among those instruments that are made for assisting us in making observations upon matter, we may find a microscope that will magnify matter two or three thousand times; and yet the most perfect of these instruments cannot make the particles of air, which are so near us, visible to the eyes. How much less can the sight, or any other of the senses, have perception of this still greatly more pure substance of the Heavens, which is at so great a distance from us? Our reason therefore, and the conceptions of our minds, must come under the corroboration of divine revelation in this. And we have the creation of the Heavens, as well as the creation of the Earth, mentioned Genesis i. 1. "In the beginning God created the "Heaven and the Earth." And Genesis ii. 1. "Thus the Heavens and the Earth were finished, "and all the host of them." And Jeremiah x. 10. "But the Lord is the true God, and an ever-"lasting King. Verse 11th, Thus shall ye say unto "them, The gods that have not made the Heavens, "and the Earth, even they shall perish from the Earth, "and from under these Heavens. And verse 12th, "The Lord hath made the Earth by his power, he "hath established the world by his wisdom, and hath "stretched out the Heavens by his discretion." Here we see in the first quoted Scripture, that the Heavens, as well as the Earth, is mentioned distinctly, and distinguished from their hosts. And when the Heavens are mentioned under this distinction, as being created and finished, this necessarily implies and denotes, that the Heavens are a created substance. And

in the laſt quoted Scripture, where it is ſaid, " And " he hath ſtretched out the Heavens by his diſcre- " tion," this evidently infolds and ſignifies, that it is ſo, that is to ſay, the Heavens were made, and prudently formed and diſpoſed. CHAP. XXXII.

It comes to be conſidered what kind of ſubſtance the Firmament of Heaven is, in which the Sun, Moon, and Stars &c, are placed, and perform their circulations. It is to be conſidered, that all created nature or beings, is either material or immaterial; or as ſome Philoſophers expreſs it, either body or ſpirit. Now this vaſt expanſe of the Firmament of Heaven cannot be underſtood to be an immaterial or ſpiritual ſubſtance, but to be void of all animal inſtinct, wiſdom or knowledge, and is merely and truly a lifeleſs and an inanimate ſubſtance. And ſo being a material ſubſtance, what mental conceptions are we to have of it, ſeeing the heavenly bodies, both thoſe that are uniform and regular, and theſe that are more irregular, perform their motions and circulations in it with the greateſt freedom and liberty.

It is to be obſerved, that between the moſt groſs and denſe matter of the Earth, and the moſt thin and pure matter of Heaven, that there is a certain gradation from denſity and groſſneſs, to purity and thinneſs. We find that Water is near twenty times lighter than ſome ſolid metals of the Earth, and that the Air is above ſix hundred times lighter than the Water; and that the element of Fire is yet ſtill greatly more thin and pure of itſelf than the Air: of which more when we come to treat of the elements of the ſublunary world. But the ethereal ſubſtance of the celeſtial regions of the Firmament of Heaven is much more, and exceedingly purer than the elements that

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compoſe the terreſtrial world. The Air is a very fluid ſubſtance, the pure element of Fire can paſs and repaſs through the moſt ſolid bodies, without penetration of dimenſions; yet it cannot do this all of a ſudden and at once, or if it do ſo, the Fire melts down the ſolid metal to a liquid, which ſhews that there is a certain ſmall quantity of matter in its ſubſtance. But the moſt pure ſubſtance of the celeſtial regions is a medium, which makes no ſenſible reſiſtance unto the Sun, Moon and Stars, that circulate therein with ſuch a vaſt ſwiftneſs and velocity. And even the Comets, with their tails or columns of vapour that adhere to them, exert their motion with the greateſt freedom; and there ſeems to be no ſenſible denſity to reſiſt them in it.

We ſee likewiſe, the vaſt difference that there is between the purity and thinneſs of the Celeſtial region, and that of the fluid Air that ſurrounds the Earth; the Air is ſtrongly illuminated by the Sun's beams, and it reflects the light back upon the Earth; this is made evident every morning before Sun-riſe, and at night after he ſets; for in the morning, as ſoon as the Sun comes within 18 degrees of the Horizon, and his beams directed in a ſtraight line over the Earth's declivity, toucheth the higheſt part of the Air, he illuminates it, and maketh the air to be viſibly ſeen with light, which it reflects by an angle upon the Earth; and in the evening likewiſe, until the Sun has got as far as 18 degrees lower than the Horizon, he enlightens the Air after the ſame manner. But the vaſt expanſe of the Stellar and Planetary regions, although at all times oppoſite to the Sun's rays, (except a ſmall part thereof, which is within the Earth's conical ſhadow) reflects no light back upon the Earth, neither can itſelf at all be ſeen.

After what has been ſaid, we ſee it is evident, that the expanſe of the Starry Firmament is a created ſubſtance, and of a moſt thin and pure nature and quality.

A ſecond thing here, is to conſider the fixedneſs and eſtabliſhment of the Firmament of Heaven. We have a little demonſtrated, that this thin and pure expanſe, is a ſubſtance ſo rare and fine, that the Heavenly Bodies exert and perform their motions and circulations in and through it as a medium, with the greateſt celerity and freedom; but that the whole of theſe expanded regions ſhould be in perpetual motion about in a circular manner, we find nothing that makes for it from Scripture, or reaſon, and obſervation, but the contrary; and to reckon that they were put in motion, it might be ſuppoſed that *that* would rather tend to obſtruct the various and different motions of the ſeveral Planets and Comets in their courſes; for the Comets have ſometimes their ſtation and courſe in the higher regions, and then by degrees deſcend in their courſe, and perform their motions in lower regions; and afterwards aſcend gradually unto the higher regions of ſpace. So alſo, the Planets move in higher and lower ſpheres, and the ſeveral different Planets move in a diverſe manner from one another, ſo that if there were a perpetual circular motion of the medium in which the Planets perform ſuch manner of courſe, this might be ſuppoſed rather to tend to the obſtruction, than to accelerate and further them in it. And when it is ſaid in Scripture, "That the Heavens are ſtretched out, and are eſta-"bliſhed for ever, by a decree which ſhall not paſs," this ſhews the immoveableneſs of the ethereal ſubſtance of the Stellar regions.

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Within the general Fabric and Firmament of the material Heavens, all thofe motions of material things is contained, whether of the Sun, Moon, Stars, and ethereal meteors in the higher regions of the Heavens, or thefe in the Firmament of the Air, and lower regions of Heaven. Such as fiery meteors, winds, clouds, rain, fnow and hail, mift and dew; and thefe on the furface of the Earth and Sea, as earthquakes, exhalations, fountains, ftreams, and evolutions in the ebbing and flowing of the Sea.

Now as the Heaven is in its nature moft fimple and moft pure, and of a different nature or quality from the elements of which the Earth is compofed, it is void of all colour, clear and tranfparent, and therefore cannot be feen; for though the Heaven feems to be of a blueifh colour, or like fapphire, yet it rather feems fo, than is fo indeed; for even the Air, though near us, it hath no colour, yet at a great diftance, it feems to be coloured; the reafon is, becaufe it is thickned, not by compofition of parts, but by difpofition; for diftance reprefents many parts to fight, difpofed all along in a vifual line.

CHAP. XXXIII.

Of the four Elements, and their Qualities.

WE come to confider more particularly, of thofe various motions which are in the Firmament of the Air, and on the furface of the Earth and Sea. It is proper here, to defcribe the number of the Elements, and their different qualities, by which they

may be known to us, as they work one upon another, and ſo effect all kind of operations. Theſe firſt qualities or tangible contraries, are reckoned to be hot, cold, dry, moiſt, heavy, light, hard, ſoft, clammy, criſp, rough, ſmooth, thick, thin, and the Elements in which theſe qualities ſubſiſt, are four; the Earth, Water, Air, and Fire.

Of the four Elements.

However the common opinion is, that if the four Elements be conſidered as ſimple and uncompounded bodies, there are in them only four firſt qualities; heat, cold, dryneſs, and moiſture. And in the combinations of thoſe firſt qualities, they thus join and unite them together; the Earth is cold and dry, the Water cold and moiſt, the Air hot and moiſt, the Fire hot and dry.

In our explication of this, the moiſture in the Water, is different from the liquidity of the matter of the Air; and when dryneſs is aſcribed to the Earth, it is not to be underſtood that the Earth is poſſeſſed of the ſame qualities with which the Fire is endowed; for the Fire is much more exquiſite in its qualities than the Earth is; and when the exact and niceſt experiments have been made upon the Air, it is found to be much more cold than the Earth and Water are.

A queſtion there is, whether theſe Elements when conſidered abſolutely in that ſimplicity which is due to their nature, and whereby they are the rule and ſtandard of mixed bodies, they are pure; but if they be compared with mixed bodies, and the queſtion ſhall be, Whether they alſo exiſt by themſelves or not, out of

CHAP. XXXIII. mixt bodies? It may be ſaid, that they are not found ſincere and pure indeed, with an abſolute purity; but with ſuch an one, as they are capable of, compared to mixt bodies. Yet although the Elements are not found exactly pure, they do not loſe their name, ſo as to be called mixed bodies; for thoſe bodies are only to be termed mixed, wherein there is ſo great a departure from the nature and purity of Elements, that the name and form being caſt away, they come to be now ſome different thing from the Elements, and receive a new and peculiar name of ſome ſort of natural body. But wherever there is ſo great an exceſs of an Element, that it tranſcends all compariſon with the reſt that are joined with it, in that the name of the Element is retained.

We come to conſider and diſcourſe a little of the nature and qualities, or properties of the globe of the Earth, and Water, or Sea, and alſo of the Air that ſurrounds or encompaſſes them about, together with the element of Fire that every where intermixes itſelf with them, and renders them to be ſo ſuſceptible and uſeful for the benefit of mankind. As it is from this view and conſideration of them, that we come to the certain knowledge of the nature and properties of Elementary matter, and of the various motions of their fluctuating particles. For ſome that have taken a contrary courſe, have run themſelves into a labyrinth of difficulties and uncertainties; becauſe it is from the obſervation of the operations of the general maſs of things, that we come to the knowledge of their proper qualities.

CHAP. XXXIV.

Of the Earth and Element of Water.

AND firſt, as to the Earth it hath much matter, and is therefore thick and dark, which is of all the Elements the moſt heavy and unfit for motion, and doth not move in any quantity of it, but by a ſtrong concuſſion of a prevailing contrary Element; or ſometimes when its duſt is reduced to the very ſmalleſt particles, they are gently raiſed aloft, by means of the impregnation of the Elements of Fire or Winds. And the loweſt and moſt centrical place is taken up and occupied by the Earth. And when free from intermixture, it is of a dry nature and quality, and is ſuſceptible of greater heat and cold than it is naturally endowed with of itſelf. But the Earth is not found pure on the top thereof; but if it be any where found pure, it is in the centre, whither no contrary does pierce that may corrupt it.

After the Earth comes the water. This Element is no where found pure, but is every where mixed with the Earth and ambient Air, of which the taſte is an argument, ſeeing you can hardly find any Water void of taſte. It is an heavy Element, yet ſomewhat lighter than the Earth, and naturally retains and keeps its place near to the Earth. And the Water is an Element in the higheſt degree, and primary moiſt, and like to the Earth in this, that it is capable of receiving an impreſſion of greater heat and cold, than it naturally hath of itſelf, as we ſhall ſee further in our deſcription of the Air.

CHAP. XXXV.

Of the Element of Air and its qualities.

AND above, and about the Earth and Water, comes the Element of Air. And it is divided into three regions; the uppermoſt, the middle, and the loweſt. The uppermoſt is above the tops of the higheſt mountains, and the loweſt reaches as far as the reflection of the Sun's beams goes; and the middle region is between them. Notwithſtanding they are all one Element of Air, and endowed with the ſame qualities, though variouſly occupied by the other Elements. The higheſt of the Air above the Earth is about fifty miles or thereby, which comes to be known by reckoning the time of twilight before the Sun ariſes in the morning, and after he ſets at night. The twilight begins in the morning, as ſoon as the Sun comes within eighteen degrees of the Horizon, then he begins to enlighten the Atmoſphere, and to diffuſe his light through the Heavens; and continues at night after Sun-ſet, until he is got as far as eighteen degrees lower than the Horizon, from which Geometrical calculation the height of the Air is found out.

As to the qualities of the Air, it is of a liquid nature, and as to its moiſture it partakes of a mean between the exceeding and primary moiſtneſs of the Water, and the dryneſs of the Earth, as the many experiments taken from its general maſs do teſtify, it being neither in the higheſt degree moiſt as the wa-

ter is, nor yet ſo exceeding dry as the Earth is, which is neceſſary in the courſe of nature for the compoſition of mixtures. And as the Air is of a liquid and fluid nature, ſo alſo it is of a very cold quality of itſelf, when it is not intermixt with the qualities of other elements or bodies, as proper experiments do make manifeſt. CHAP. XXXV.

A very full proof, and moſt certain evidence of the coldneſs of the Air ariſes from the way and manner by which froſt, ſnow, and hail are propagated and diffuſed upon the Earth and Water. As froſt and ſnow are of themſelves of the coldeſt quality of any thing known, and if the Earth and Water of themſelves propagated the froſt, the Earth would firſt be frozen below, and the Water at the bottom or middle depth of it. And if there were heat in the ambient Air, that ſurrounds the Earth ſo cloſe, there might be froſt below in the Earth or Water, and at the ſame time thaw upon the top of the Earth and Water; but the contrary of this is the caſe. For the froſt always begins above, and goeth downward in the Earth and Water, and doth never begin beneath, and ariſe upward.

And if it ſhould be ſaid, as is the caſe of the froſt, ſo alſo is of the thaw, for the thaw begins above, and goeth downwards when it exhauſts and melts the froſt out of the Earth and Water; and therefore the Element of Air may be the inſtrumental cauſe of the thaw rather than of the froſt. But to this we muſt obſerve, that the cold is a poſitive quality, and all poſitive qualities muſt be inherent in, and proceed from a certain ſubject.

It is obſervable indeed, according to the ſenſe of mankind, that the Earth and Water, in moſt places,

CHAP. XXXV. very often, and for the moſt part of time, appear to be more cold than the Air. This being agreeable to the general feelings of mankind ſo to be; for when upon trial, a perſon holds up his hand into the Air, and afterwards thruſts it downwards into the ſoft Earth, or dips it into the Water, he feels the Earth or Water more cold than the Air, moſt frequently. And experiments of this are to be found in ſummer, rather than in winter; and in winter in the time of thaw, rather than in the times of froſt; and this in all climates where froſt is frequently to be found. But in very cold climates when the experiment is made, in the time of exceeding intenſe froſt, it is found to be otherwiſe. For, in the coldeſt climates, when the froſt is intenſe, when a man has made another trial, by putting his hand into the Water or Earth, below the froſt, and afterwards holds it up in the Air, he then and there feels the Air to be ſenſibly colder than the Water or the Earth. For in thoſe places, and at theſe times, the Air is more pure and free from intermixtures, and more of a piece with itſelf, which makes the experiment to be more juſt and certain.

But over the greateſt part of the Earth, eſpecially over warmer climates, and at moſt times, the Air by impregnation with, or having its interſtices filled with other heating cauſes, there cannot be any juſt experiments made upon it, and a proper judgement formed as to its qualities of heat or cold, as the Air is the vehicle through which the Sun's heating rays paſs to the Earth, or repaſs from it, (as we will more fully ſee when we come to treat concerning the Element of Fire) and the Earth's Elementary heat itſelf, that aſcends upwards in the ſteams and vapours that ariſe up from its ſurface into the air. Theſe make ſuch a

metamorphosis in the Air, that its true and real qualities cannot be sensibly known. The Element of Fire that is in the Air, which proceeds from those heating causes under the warmer regions, so alters the temperament of the Air, that it becomes soft, and not so piercingly cold as the Earth or Water; and especially, as itself is under the Frigid Zones.

For which reason, the greater part of ancient Philosophers, who lived under the Temperate or the Torrid Zones, and who wrote upon Pneumatics, and nature or qualities of the Air, were of opinion that it was hot; they having made their experiments and observations, either in the more warm, or in the hot climates, which was the occasion of their receiving this opinion. But under the cold and Frigid Zones in the winter time, when the Sun is below their Horizon, and his direct or oblique rays do not pass thro' the Air within the Earth's shadow, so as to draw forth, or cause reflex heat from the body of the Earth to warm the Air, there, and in these places, the Air makes manifest, and shews forth most of its natural quality of cold, by congealing and freezing the surface of the Earth and Water below it. And without this view and consideration of the quality of the Air, a reason cannot properly be rendered for the being of frost upon Earth, and of the snow falling from the Air, and more especially, why the frost affects the surface of the Earth above, when there is none below, and congeals the water on the top, when there is no frost in the bottom of it; and also, why springs and fountains that arise up out of the Earth, do not freeze, when all standing Water on the Earth about them is frozen.

But that the cause of frost doth not proceed from

CHAP. XXXV. the Earth and Water, is plainly evident from the reason already given; that they are always affected firſt upon their ſurface, and ſo on downwards; and good ſpring fountains, that ariſe from the bowels of the Earth, do not freeze; and all deep pits, that go down into the Earth, the froſt is not found at their bottom in winter time more than in ſummer; and the bottom of deep ſeas, even in the moſt northerly climates, do not freeze. Therefore, the froſt is impregnated in their ſurface, from ſome external cauſe, that is colder than they are, and doth not flow out from, or proceed from the body of the Earth or Water themſelves. And that the quality of cold is an inherent property in the Element of Air, is manifeſt from the ſnow and hail that are in the airy Firmament above; even before, or when there is no froſt on the Earth below. And that we find heat and warmth from the Air ſometimes, it proceeds from this, that its interſtices are the more occupied by the Element of Fire and the Sun's beams, or the influences of the Conſtellations of the Heavens, which makes it render and convey as a medium, theſe warming and heating qualities and influences upon the Earth, at ſometimes more than others.

The Air alſo, although it be of a fluid and Elaſtic nature, yet it hath ſome conſiſtence, and hath a conſiderable weight, which ſerves as a natural cauſe, to ſupport and bear up the clouds and other meteors, that are raiſed aloft and fluctuate in its territories.

And as the Terreſtrial world, is as one united body, compoſed of four different Elements, wherein there is no vacuum, except it be made by a miracle, or ſome artificial force, and all the particles of matter ſhut up and compacted together, as cloſe as matter can be. The four Elements, although they are of different na-

tures, and endowed with different manner of qualities, they all are unite in this, to join themſelves together, and make up one compounded body. And the great fluidity and elaſticity of the Air, gives it a power to ſerve this purpoſe: for the Air inſinuates itſelf, and makes its way into all the porous parts of the Earth or Water, wherever they are; although theſe particles of Air, when in this ſituation, continue diſjoined from the reſt of their own Element, and when theſe pores of the Earth or Water are ſhut up, either by the courſe of nature, or art of man, as in ſome ſmall inſtances, theſe particles of Air return again to their own general maſs, when freed from reſtraints.

The nature of the Air cannot be changed, for every thing ſeems to prove to us, that it is a ſubſtance of which the nature is fixed, of which the integral parts are ſimple, homogeneous, and of which the principles are ſo united, as never to yield to any efforts that can be made for reſolving and decompounding them; and is a very univerſal Element, and moſt neceſſary for the preſervation of every being endowed with life on the face of the Earth. It is the Air that makes waters evaporate, plants vegetate, and keeps man, and all the animals we know of, in life and ſpirits: Air is the vehicle of light, ſounds, odours, &c. However, the loweſt region of the Air is variouſly intermixed and diſpoſed, ſometimes it is hot, other times cold; ſometimes moiſt, other times dry; ſometimes clear, other times cloudy, as it is differently intermixed and affected with the other Elements of Fire or Water. And the Air being in this region variouſly diſpoſed, does diverſly affect our bodies; for while we breath, we continually draw it in, and by it the ſpirits in our bodies are repaired and cheriſhed,

CHAP. XXXVI. and our heat, while in the body needs continual fanning, is thereby preserved.

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Of the Nature, Qualities, and Properties of the Element of Fire.

WE come now to consider the nature and properties or qualities of the Element of Fire. Now, the Fire of itself, is a substance most subtile and thin, piercing through all things, which neither shines, nor is seen, whilst it is pure and simple without any mixture; and the exceeding lightness of the Fire, is attended by exceeding rarity, and it hath least matter of all the Elements, and amongst natural things in the sublunary world, it comes nearest the nature of form; and therefore, it hath the greatest activity of all the Elements; yet when it is pure and of itself, it does not burn; but that it comes to burn, the cause is in that it is condensed, and sticks in, and adheres to gross matter; whence its parts being condensed and brought into a narrow compass, acquire and attain the greater force. The Elementary Fire, is not of itself at all visible, the Air in the Penumbra, appears of a light blueish colour, and the material Heaven seems to be of a sapphire or blue colour, though not by composition of parts, but by disposition of the many parts represented to our sight all along in a visual line. But the pure Element of Fire, when not condensed and mixed with gross matter, was never seen with mortal eyes, nor can be seen; therefore, when we treat upon

the qualities of this Element, we are rendered under an abſolute neceſſity to reaſon from the effects to the cauſe. CHAP. XXXVI.

This Element of Fire, being a ſubſtance moſt ſubtile and thin, with lightneſs and exceeding rarity, and its particles are moſt minute and ſmall of any thing known in the whole ſyſtem of Terreſtrial matter, which renders it to be in a condition, or qualified and fit to intermix itſelf with, and make its way through the other Elements, and all material things, or bodies whatever. And its moſt pure thinneſs and fluidity, qualifies this Element to be the moſt agile and quick in its operations, through or upon the other Elements and bodies, of any other material ſubſtance.

After having given this ſhort definition, of the nature and qualities of the Element of Fire, we now come to conſider its place, that it occupies and poſſeſſes in the ſyſtem of nature, (and as hath been before obſerved) this muſt be known by its effects. For its innate and pure ſubſtance, when not intermixed with other things, does not come under the perception of our ſenſes, and for this we muſt underſtand, that it is poſſeſſed of, and operates through a very large place, even through the whole of the known ſyſtem of material nature itſelf.

The Element of Earth hath its circumſcribed bounds, within a ſmall compaſs, in the centre of material ſpace. And the Element of Water, that hath its place and ſituation near to, and adjoining the Earth, with all its effluviums of miſts and clouds, hath likewiſe but a ſmall compaſs, and is contained within narrow bounds in ſpace. And alſo, the fluid Element of Air, that ſurrounds the Earth and Water every where, and even fills their

CHAP. XXXVI. interſtices, as much as the nature of its Element can do; the height of the atmoſphere of Air, that reflects the Sun's rays, for what is yet known, does not exceed fifty miles above the Earth; and ſo this Element, properly ſo called, even in its utmoſt extent, is contained within a compaſs of ſmall limits in the material ſyſtem. Theſe three Elements compoſe and make up the bulk of the viſible and ſublunary world. And the bodies of the Sun, Moon and Stars, that circulate in the ethereal and celeſtial world, are comprehended within a certain and limited ſpace, in that pure material expanſe: all theſe Elements in the ſublunary world, and thoſe bodies of the Sun, Moon and Stars, in the pure ethereal and celeſtial world, or Firmament of Heaven, have their circumſcribed limits and bounds in their different ſituations, from which they never deviate, or go from, but keep their due diſtances in their own proper ſpheres at all times.

But this Element of Fire hath a more general extenſion than the other three Elements below, or even that of the bodies of the Sun, Moon and Stars above, for the effects of its influences and operations, are manifeſtly known to be in the Earth, and in the water below, and to be in and through the Air above; and we are moſt certain, that the Sun is endowed with and communicates elementary heat. And alſo, the influences of the Stars and Conſtellations themſelves, are diffuſed and conveyed to the Earth by this inſtrument, through the vaſt expanſe of the Heavens; ſo that the Element of Fire, when ſimply conſidered in an abſtracted view, hath place in the ethereal or celeſtial Heavens, in the Air, and in the Earth and Water. And although the body of the Sun, of all others known to us, be moſt endowed with heat, yet

this moſt pure Element, operates in a leſſer or greater degree through material nature, in ſuch a manner, and by ſuch proportions, as the All-wiſe Creator and Governor of the world ſees meet. CHAP. XXXVI.

And that this pure Element of Fire, hath place in any particular ſpace, where no other matter exiſts, is a thing altogether unknown, nor is there reaſon to think ſo. Some indeed have been of opinion, that there is pure elementary Fire under the ſphere of the Moon above the Air, and there it hath its reſidence, in a certain ſpace, from whence it is diffuſed through the Air to the Earth. But as to the opinion of theſe men in this matter, we incline to think otherwiſe, becauſe of the exceeding rarity and purity of its nature; for no Elements or bodies whatever, are ſo denſe as to hold it out, nor their particles ſo ſhut up together, and cloſe compacted, as to keep it in; and it intermixes itſelf with the other Elements or bodies to a certain degree, and when not carrying along with it any groſs matter, the Fire goeth through, or remains in the other Elements or bodies, even without the leaſt penetration of dimenſions, and is as an univerſal handmaid (ſo to ſpeak) to the reſt of matter, as having place in the Sun, and in ſome degree in the Stars, and in and through the ethereal celeſtial Heaven, and alſo in the Element of Air, and in the body of the Earth. And it hath place, and even operates in Water, and is as an inſtrument of conveyance and communication between the Sun, Moon and Stars in Heaven above; and the Air, Earth and Water below. And for any thing that can be known otherwiſe, the Element of Fire doth not exiſt purely in any place by itſelf, but hath place both in the ethereal Heaven, and through all the Elements of the ſublunary world, either in a greater or leſſer quantity.

CHAP. XXXVI. The next thing to be ſpoken to, is concerning the weight of this Element of Fire. But it is a material ſubſtance, of ſuch an exceeding levity and purity, that its weight cannot be found out. For no experiments that can be invented, will aſſiſt in doing of this. For although one heat a globe of iron, or any other denſe body, red hot, and then put it into the ſcales and weigh it when hot, and then weigh it when it becomes cold, this will not be a juſt experiment for finding out the weight of the Fire therein. For as the Fire goeth out of the globe when cooling, it evaporates and carries along with it a number of ſmall particles of matter that are of ſome weight, which makes a difference between the hot and cold globe of metal when tried. But ſetting aſide this, and all other experiments that can be thought upon by man, this is of ſuch exceeding purity and levity, that its weight cannot be known.

We now, according to our purpoſe, and the deſign of our ſubject, come to conſider the motions of this Element of Fire, which of all the other Elements in this ſublunary world, or of all bodies, or meteors in the ethereal and celeſtial, it is the moſt quick and various in its motions, paſſing both downwards and upwards, and ſideways, or obliquely and aſlant, very ſuddenly. And although there be ſome degrees of this Element in all material things, yet there is much more of it in ſome things, than in others; and it comes chiefly from the Sun, and even from the Moon and Stars in ſome ſmall degree, through the Air, and in the Earth and Water, and paſſes, and repaſſes in all different directions, both upwards and downwards, or obliquely.

Julius Caeſar Scaliger, and others, when endea-

vouring to prove that there is pure unmixed Elementary Fire under the circumduction and ſphere of the Moon, they thus argue, That the Element of Fire being exceeding light, it therefore hath a perpetual endeavour to aſcend upwards; for it is of all Elements the moſt light and thin body, as next in place to Heaven, ſo in nature moſt of kin thereto, unto which alſo, if forced therefrom, or generated elſe where, it tends as to its proper place. And ſay they, the ſmoke which aſcends hath very much fire in it; for it aſcends not becauſe of Water, much leſs becauſe of Earth; nor does that motion proceed from the Air, for it is already in the Air. What place therefore does it ſeek? that place verily which is above the Air, is due to the lighteſt of bodies; and every ſpace to which a body naturally moves, is the proper ſpace of that body. The Fire moves naturally upwards; therefore the ſpace above, is proper to the Fire.

In anſwer to this, the Element of Fire, when unmixed with other things, is a ſubſtance of ſuch exceeding thinneſs and purity, that its particles have acceſs in and through the fluid Element of Air, and even in and through the more denſe Elements and bodies, without penetrating their dimenſions, when it moves gently, without much attractive force. So that when it is ſtrictly and abſtractly conſidered upwards and downwards, makes no difference of place for this Element. And that the Fire in our kitchen, or in a lighted Candle, aſcends more upwards than downwards, it is cauſed ſo to do by reaſon of flame and ſmoke that carry it upwards, more than any other way. For the Fire hath ſuch a quality, when it hath the predominating power over any elementary body, that it reduces its particles of Earth and Water

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into such exceeding small atoms, that they become lighter than the Air, and while they continue so, they still mount upwards and the Fire along with them. For it is agreeable to the nature of this sublunary and material world, and the laws of Hydrostatics, that all heavy matter and things tend downwards; and so all light matter and things must give place to them, and are pressed upwards.

And that the particles of the Earth, and especially of the Water, may be reduced so small as to rise above some part of the Air, and consequently are lighter than the Air, is evident from this manifest experiment in the works of nature, which we see in the mists, clouds, and other meteors that are raised aloft, and borne up and carried by the Air. The natural cause of this is, that these clouds or meteors are compounded with, and intermixed with this Element of Fire, which both rarifies their particles, and keeps them asunder, that they come upon the equilibrium with that sphere of the Air in which they move or rest suspended. And when this composition or intermixture of this hot Element, with these liquid clouds, or the more dry meteors, is broken by a predominating quality of cold, they condensate and turn a little more heavy, and return downwards.

The Element of Fire having free egress in matter, when come down from the bodies in Heaven, or drawn up from the body of the Earth by reason of mixtion with moisture, they both ascend up together in the Air. But these different Elements, in this compound of vapours, arise upwards by different laws of matter. The Element of Water in these vapours arises upwards by reason of its levity, which is produced in them by their being rarified with the quality

of heat which is in them, which renders their exceeding minute particles ſo much lighter than the body of the Air in which they ariſe. CHAP. XXXVI.

And, as was ſaid before, concerning terreſtrial matter, that which is heavier takes place below, and that which is lighter gives way to it, and ariſes above it; ſo moiſt vapours mount upwards, when their particles are reduced ſo ſmall as to be lighter than the Air.

But the pure Element of Fire, when conſidered by itſelf, and not intermixed with other matter, is not an Element altogether confined to the terreſtrial Globe; but mounts up from the Earth to theſe bodies in the Heaven, and deſcends from them to the Earth, and is in ſome greater or ſmaller degree in moſt, if not in all theſe bodies in the Heaven, and alſo in the Earth, and likewiſe in the intermediate ſpace between them, and moves hither and thither, by a ſympathetic and attractive virtue that is in this Element, from the different places and bodies in which it is, or rather from an expreſs commiſſion by the wiſe Author and Diſpoſer of matter (of which more afterwards) it is from the attractive or diffuſive virtue that is in this pure Element of Fire, it being one chief inſtrument of communication between the Heavenly bodies and the Earth, that the natural reaſon of the Phenomena or appearances of meteors in the Heavens, or vapours in the Air, is ſolved, and alſo of the effects and operations that it makes in natural bodies.

And although ſome have endeavoured to exclude the Fire from among the Elements, yet no ſound Philoſopher denies that Fire does belong to the Elements which make up the material World, and conſtitute mixt bodies. For heat, which is a moſt manifeſt and effectual quality, and is accidentally in many things,

CHAP. XXXVI. therefore, there muſt of neceſſity be ſome firſt ſubject wherein it is primarily and eſſentially; for nothing is in any thing accidentally, which is not eſſentially in ſome other thing primarily and of itſelf. And the firſt ſubject of heat is Fire, at firſt created by God, with the other Elements, and furniſhed with its qualities. And its moſt ſubtile and thin ſubſtance qualifies it for mixture with the other Elements and mixed bodies, and inhereing in them, and yet at the ſame time not to be perceived by our ſenſes, until its power predominates and prevails over the other Elements or matter with which it is compoſed, and then it diſplays itſelf in the moſt open and manifeſt manner.

And now, perhaps, a queſtion may be propoſed after what has been ſaid above, concerning this Element, Whether that *that* Fire, which is potentially in Heavenly bodies, and particularly in the Sun, be of one and the ſame nature with the Fire that is intermixed with the Elements and matter of the Earth?

We, in treating upon this Element, have hitherto reaſoned from the effects to the cauſe, and from the cauſe to the ſubſtance. And after trial by experiments upon the heat that comes from the Sun, it is found to be of the ſame nature, or to have the ſame effects with that which is extracted from any denſe body, or produced from combuſtible matter. The Fire which is in any elementary earthly matter, when brought to be the prevailing Element therein, it not only conſumes and burns the matter from which it was kindled and bred, but likewiſe burns up other combuſtible matter which is added thereto. So in like manner, Fire may be kindled by the Sun-beams, which will have the ſame effect. For it is a thing of itſelf manifeſt, and well known, that by burning

Glaſſes, and other Glaſſes ſet in the Sun-beams, that wood, paper, and other dry things, are ſet on Fire. We have a well known remarkable ſtory, how that by means of burning Glaſſes, Archimedes ſet on Fire the enemies gallies, and burnt them up. So Fire is all one and the ſame Element, wherever it exiſts.

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Of Fiery Meteors.

HAVING ſpoken in general of the Elements, the principles of natural bodies, we now come to conſider how they operate upon one another, as the natural cauſe of thoſe various motions that are in the Air, ſuch as fiery meteors, winds, clouds, rain and hail, miſt and dew.

And firſt, as to fiery meteors, the greateſt part of which are bred in the uppermoſt region of the Air. For when hot and dry exhalations do aſcend thither, and are there inflamed, ſundry fiery meteors are engendred, which differ according to the various diſpoſition of the matter, the diverſity of inflammation, their magnitude, figure, motion, and duration. Of which, though more ſorts might perhaps be reckoned up whoſe names are borrowed from the ſhapes which they repreſent in their burnings, yet I ſhall recount the chiefeſt of them. Firſt, there are many fiery meteors do ariſe, differing only in the poſture of the matter, the multitude and ſhape they repreſent while they burn, which are to be explained.

And that we may begin here, If an hot and dry exhalation, not very thick and fat, but ſubtile, ſtretched

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out in length and breadth, do take fire in the upper region of the Air, there appears a burning and ſhining flame, ſometimes with ſo much brightneſs, that doth a little diſpel the darkneſs of the night: ſome are pleaſed to call this meteor burning ſtubble, for it repreſents fields of ſtubble ſet on fire.

Secondly, The Running Stars, or Flying Stars, as ſome call them; becauſe they appear in the ſhape of Flying Stars. This does happen, when an exhalation in the upper region of the Air, drawn out in length, is torn, diſtinguiſhed, and ſpread abroad into many particles as it were; for the firſt part being inflamed, doth ſpeedily communicate the Fire to the other, the ſecond to the third, the third to the fourth, &c. After the ſame manner, as a candle lighted doth eaſily light another again newly blown out, and ſo makes ſhew of a Shooting Star. Again, when an exhalation ſubſiſts in the middle region of the Air, and either by the antiperiſtaſis of the cold Air is inflamed, made lighter, and ſo raiſed on high, and appears like a Flying Star; or, being by the coldneſs of a cloud compreſſed and ſqueezed, it conceives Fire and moves downwards, for the moſt part ſide-long and violently, and then a Star ſeems to fall from Heaven in appearance. For we muſt not give credit to the dotage of thoſe, who taught that the Stars did really fall from Heaven, for there is no night wherein ſome Shooting Stars appear not, and yet the Stars of Heaven appear in the ſame place they were in before. When many Shooting Stars appear, they foretell Winds to follow; for they argue ſtore of dry exhalations beginning to ariſe, which are matter for Winds.

Thirdly, The Flying Dragon is engendered in the middle region of the Air. Now, this meteor is made,

when an exhalation a little clammy and hot meets with a cold cloud; or, by antiperiſtaſis of cold Air, and is thereby driven back and flies from it, in its upper part, where it is lighter, it is ſet on fire, and ſeems to vomit flames and ſparkles; but in its middle part, where it is thicker, and is bowed, it repreſents a belly; and in its lower part, which is narrower and ſtraiter, it reſembles a tail.

Beſides, there are ſeveral others; ſuch as Skipping Goats, the Burning Brands, the Burning Spear or Dart, the Burning Pillar, the Candle or Torch, and the Ignis Fatuus; and alſo, in the warmer climates are bred theſe meteors, called Helena, Caſtor and Pollux; which are wont commonly to be ſeen of mariners at ſea in time of a tempeſt, and fall down ſo low ſometimes, as to ſtick to the maſts of ſhips.

Having mentioned the ſeveral ſorts of meteors that are obſervable in the different regions of the Air, our next enquiry is to conſider how they come to be there, and ſo engendered in their different magnitudes and figures; for the pure Element of Air of itſelf, when not mixt with other things, is not inflammable; and the matter of meteors, for there are ſometimes more and ſometimes fewer meteors in the Air, according to the diverſity of exhalations and matter that is intermixed there, the Heavenly bodies are the efficient cauſe, which raiſes exhalations in the Air, and the Earth is the ſubject out of which fiery meteors are exhaled and raiſed up into the Air, and the Element of Fire, is inſtrumentally ſerviceable or contributing to, as a means of communication between the Heavens and the Earth, and is in ſome degree leſs or more potentially in all mixt bodies. Now, the ſeveral particles of this Element, have a conſent and

CHAP. XXXVII. mutual appetite one to another. Hence, Fire is eaſily drawn by and united to Fire, and the exceeding thinneſs and purity of this Element, gives it free egreſs and acceſs every way through the Heaven and the Air, and when a number of the diſperſed particles of the Element of Fire, are drawn up out of the Earth, as ſaid is, and when they carry along with them dry matter, not very thick and fat, but ſubtle, into the regions of the Air, and by the antiperiſtaſis thereof, it is ſet on Fire, and flies back, until the matter be conſumed and diſperſed.

CHAP. XXXVIII.

Of Winds.

AFTER the fiery meteors, we are to treat of Winds, which in itſelf, is a ſubject ſufficiently obſcure; and to give a full and ſufficient definition of its cauſe, is a matter above the reach of human underſtanding and reaſon fully to determine. That Wind proceeds both from an agitation of the Air itſelf, and from other matter with which it is incorporated many times, is a thing evident and demonſtrable; but the firſt natural cauſe of that agitation and motion, is to be the inquiry. That the pure Element of the mixt Air, of itſelf and alone, does not move and cauſe Wind, is agreeable to the nature and laws of that Element, when conſidered ſimply in itſelf, as being ſerene and at reſt, and not diſturbed and moved by an external cauſe; and alſo, that Wind is not cauſed by the pure and unmixt Element of Fire that may be

in the Air, is alſo evident; for when there are moſt heat in the Air, there is leaſt Wind and motion in it, when that heat comes intenſely downwards upon the Air.

But when Fire, that moſt moving and fluctuating of all the Elements, is drawn up from the body of the Earth and Water, by the attractive heat in the Heavenly bodies, and with it a greater or leſſer plenitude of exhalations of matter either more dry or more moiſt, and are drawn up to the firſt or ſecond region of the Air, and are there repelled and kept within the circumſcribed bounds appointed and aſſigned for the effluviums and ſteams that ariſe from the Globe of the Earth, they then make their egreſs by moving athwart or acroſs, and cauſe an agitation and motion in the Air, while the ſuction of theſe exhalations from the Earth or Water laſts, which at ſometimes continues for ſeveral days or weeks together. And whatever way the Air is agitated, the particles that are ſet in motion, by quitting their places, oblige the neighbouring particles to give way to them; and ſo on, every particle moving another forwards. And though the violent motion of the winds be chiefly to be attributed to exhalations, yet the Air itſelf doth increaſe that motion, which being moved by the exhalations, is itſelf agitated, and forcibly carried this way and that way, or ſtraight forwards; the firſt compreſſed Air becoming more elaſtic, and by its ſpringingneſs, it beats upon the neighbouring particles, and with an undulatory motion, they are driven to and fro, or impelled and forced in a ſtraight courſe, as long as the firſt cauſe of this agitation and motion continueth.

And now, although one chief cauſe of Winds proceeds from that communication which is between

CHAP. XXXVIII. the Heavenly bodies and the Elements of which the ſublunary world is compoſed, and the intercourſe that proceeds from the Element of Fire that is in them, with that which is in the Earth, and virtually drawing forth exhalations from the body of the Earth and Water which impregnates the Air, in that place where they ariſe, and in moving athwart they carry the Air along with them the way that they direct their courſe, yet in this there is a great variety of different motions which ariſe from the nature and qualities of the Earth in different latitudes and climates, and even in the different ſeaſons of the year, according to the degree of heat that is ſhut up in the Earth or Water in thoſe places from whence the exhalations ariſe.

Under the Frigid and Temperate Zones, the wind blows at diverſe times from all the different points of the Heavens. And under the Torrid Zone, within, or near the Tropics, the wind blows moſtly from the eaſt, directing its courſe in towards the Equinoctial Line; this is called the Trade Wind. And in the Indian ſea, there is a wind called the Monſoons, which blows in towards the land, moſtly for ſix months of the year together; and out from the land towards the ſea, for other ſix months time. And in and about ſome Iſlands, the wind blows in from the ſea, upon the land in the day-time, and out from land towards ſea in the night-time. And the force and ſtrength of all winds whatſoever, ariſes from the quantity of the exhalations that are raiſed up; and the quality of the repercuſſions that are in the Air above, when they are aloft.

Alſo here, is to be remarked the temperament and quality of the winds. For though they all agree in matter, and conſiſt of an hot and dry exhalation; yet

ſince that is ſeldom raiſed up alone, but for the moſt part out of the Sea and the Earth, watered with rains and ſnows. Theſe two exhalations are drawn together, and afford matter to the wind. Moreover, that they paſs through places that are hot, dry, or cold. Therefore, there is alſo a great difference of winds in reſpect of the places from whence they ariſe, and through which they blow. For the winds have not only the qualities of thoſe places from whence they ariſe, but their chief qualities they have from the places through which they paſs. CHAP. XXXVIII.

Having now ſpoken of the riſe, cauſe, and continuance of winds, we come to conſider next, how they again decreaſe, and ceaſe from blowing; and the Air again comes to be at reſt. This comes to paſs two manner of ways; either when the exhalations themſelves, which are the cauſe of winds and agitation in the Air ceaſe from riſing upwards into the Air, and then give over putting it any further into motion; or otherwiſe it comes to paſs, and be in thoſe places and countries that are at a conſiderable and due diſtance from the places where the exhalations that are the cauſe of the motion ariſe. For exhalations that are the cauſe of the winds, after they bave been long up, moving athwart, a-croſs the Air, to a due and proper diſtance, according to the degree of their ſtrength, they again gradually decline and loſe their force, both by the repercuſſion of the Air itſelf, in which they move, and alſo the ingredients of which their ſubſtance is compounded gradually ſeparates and diſunites, the more pure part of the compound, which the Element of Fire evaporates, and by degrees ſeparates from their more groſs parts, and then theſe inſenſibly return and fall downwards.

CHAP. XXXVIII. An emblem of which, we have in the ſmoke that ariſes from the Chinney-piece, it firſt riſes upward, and then it moves athwart, and this it doth while the heat and fluctuous vapours are incorporated. But after the heat evaporates and ſeparates from the groſs matter, its particles fall down again; and this is moſt evidently ſeen to be the caſe, when there is a white ſnow upon the ground, theſe black particles lie ſcattered upon it below, on that way where the ſmoke hath its courſe.

CHAP. XXXIX.

Of Clouds, Rain, Snow, Hail, Miſt, and Dew.

HAVING hitherto explained thoſe meteors which are bred of hot and more dry exhalations, we come now to thoſe which are bred of a moiſt vapour, in the middlemoſt and loweſt regions of the Air. In the middlemoſt region are ingendered clouds, rain, ſnow, and hail.

Of Clouds. A cloud is ingendered when moiſt vapours are raiſed aloft, by the attractive heat which they have received from the Sun, and other heating cauſes; and by hot exhalations mixt with them, are aſſembled in the middle region of the Air, and theſe moiſt exhalations when they firſt ariſe, they ſometimes cannot be perceived by the ſight; for the cloud that ariſeth out of the Sea, like a man's hand, may inſenſibly increaſe until the Heaven be black with clouds. For a cloud is a pure moiſt vapour raiſed up in the middle

region of the Air, and there compacted, and becomes more denſe before it turn to rain. CHAP. XXXIX.

But the clouds that remain in the Firmament of the Air, although at a diſtance they appear to the ſight to be thick and compacted, becauſe their parts are diſpoſed along in a viſual line; and they that walking beneath ſee clouds upon the Mountains, yet when they aſcend to the tops of the ſaid mountains, they walk through the clouds as through miſts there.

And as to the height of the clouds, it is certain that they are conſiderably higher than the tops of the higheſt mountains, in all rainy countries. For the ſtorms of rain that fall upon them, and the ſnows that lie upon them in winter-time, make this evident. However, they are higher at ſometimes than at others, according to the variety of the matter, places, and times. And we often ſee with our eyes, that at the ſame time, and in the ſame region, one cloud is higher than another, and that one goes above another. I myſelf have ſeen two clouds carried with contrary motions, and the one moving above the other towards the weſt, and the other moving under it towards the eaſt.

The colours of the clouds are various, according to the various diſpoſition of the matter, receiving the beams of the Sun or Moon. And about the edges of ſome of them, they appear coloured, white, or red; the vapour there being thinner ſpread, ſo as the Sun's rays pierce through them; and thoſe that are black, are more thick, and darken the rays of the Sun, ſo as they cannot enter into the vapour of the cloud, which is more thick.

Now as the clouds are compacted with a watery ſubſtance, and Element of itſelf, when condenſed,

CHAP. XXXIX. is much heavier than the Air. Therefore the natural cauſe how they remain ſuſpended in the Air is, that the Element of Fire is there incorporated with the Element of Water. As the Element of Water is much heavier than the Air, ſo the Element of Fire is much lighter than it is. And as there is a certain communication between the Element of Fire that is in the Heavenly bodies, and that which is in the Earth and Water, when that ſuperiour heat, which is in the Heavens, attracts this inferior heat that is in the Globe of the Earth, it exhales and carries up with it moiſt vapours from both the Earth and Sea. And theſe moiſt particles being ſo very ſmall and light of themſelves, together with the heat that is in and about them, they become lighter than the Air. And according to the law of Statics, they move upwards, until they unite a little more cloſe in the place aſſigned for this effluvia, and there they ſwim or reſt ſuſpended in perfect equilibrium with the Air, in that place where they move or are at reſt.

Some clouds are termed barren, which are white and tranſparent, and never turn into ſhowers of rain; and when the Element of Heat, that is in them, being attracted aloft, and ſeparated from them, while their ſmall particles are ſpungy and diſunited, then like the miſt, they then imperceptibly diſſolve and fall downwards again. For rain is nothing but a cloud, cooled, condenſed, and turned into water. And rain is bred, when the vapours which make a cloud are yet more condenſed, and turned into water, which being heavier than the Air falls down of its own accord in drops. For when the ſmall particles are united in little bodies, by reaſon of cold, that thicken their parts, they turn heavy, and this breaks the equilibrium with

Of Rain.

which they were ſuſpended and reſt aloft in the Air. And rain is made after the ſame manner as hot vapours on the walls of Baths, or in the winter in hot ſtoves, upon Globes of glaſs, iron, or tin jugs that are cold, the vapours we ſee are turned into watery drops.

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Now there are ſome diverſity of rains proceeding from the variety of clouds, and of their place, which is ſometimes higher and ſometimes lower. For when the cloud is high, unequal, ſpungy and barren, and few ſmall drops fall like dew, they are called hot drops; but if the cloud be more near and compacted, and the drops fall down thicker, it is called a ſmall ſhower. Finally, if the cloud be yet thicker, and ſuddenly condenſed by a greater cold, and greater drops fall more thickly, it is called a ſtrong ſhower; yea, and ſometimes within the Tropics, clouds are ſo condenſed by a ſudden cold, that the waters deſcend not drop by drop, but come down in ſtreams to the great damage of towns, cities, and ſhips at Sea; theſe are called Water Spouts.

Of Snow.

Of the ſame matter with rain, is ſnow alſo made. For ſnow is bred of a vapour raiſed to the middle region of the Air, or ſomewhat lower, or of a thin cloud (before it is turned into water or rain) congealed by vehement cold, and torn into parts or flakes, which deſcend like ſoft wool, ſometimes greater, other times leſſer, according to the vehemency of the cold. Now ſnow is bred in the winter time, chiefly becauſe the cold is then great and vehement, ſo that it is not only able to condenſe vapours into clouds and rain, but alſo into ice; for ſnow is nothing but a kind of ice bred in the Air; which by the bye demonſtrates to us the coldneſs of the Air, when much diveſted of the Element of Fire, by the Sun's heat being withdrawn from it.

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Now ſnow is white, becauſe it is ingendered of a ſpungy tranſparent cloud; and that which is tranſparent, after it is terminated, doth next of all become white, becauſe that colour is moſt a-kin to tranſparency. This appears in cryſtal or tranſparent Glaſs, and clear Ice, whoſe ſurface, if a man render uneven, ſo that it is no longer tranſparent, or break and grind it into ſmall parts, in room of tranſparency, whiteneſs is produced. It happens ſometimes, that when the lower region of the Air is a little hotter than ordinary, the ſnow as it falls down doth melt when it comes there, and ſo that which is ſnow above, is rain below; and therefore, frequently when it rains in valleys, it ſnows on high mountains; and for the ſame cauſe, there is ſnow on the higheſt mountains, when there is none to be ſeen on the plain ground.

Of Hail.

Beſides rain and ſnow, of the clouds alſo there is bred hail; for hail is nothing but congealed rain. And it is bred, when a cloud is diſſolved into rain and deſcends, and in its coming down, by extremity of cold it is congealed into little round balls. If the cold be remiſs, a certain imperfect and ſoft kind of hail is bred of a middle nature, betwixt true hail and ſnow, and reſembles ſmall ſugar plumbs; and this falls chiefly about the end of winter. And before the falling of hail, for the moſt part, great ſounds are heard in the Air, which are cauſed by the great conteſt of heat, and cold in the clouds.

Of Miſt.

As alſo of a vapour ſome meteors are generated in the lower region of the Air, ſuch as miſt and dew. Miſt is cauſed when there is great ſtore of vapours exhaled from the Earth or Water; and drawn up only in the lower and warmer region of the Air, and being

preſerved on the vicinity of the Earth and its warming influences, and continued below the cold influences of the ſecond region, this keeps the particles from being thickened, and they diſſolve and fall downward without turning to rain. This kind of miſt is a token of fair weather to follow afterward. There is another miſt which conſiſts of thicker vapours exhaled out of the Earth, which alſo by reaſon of their thickneſs and ſmall heat in them, cannot be carried aloft, but ſettles in the loweſt part of the air; and ſo they cauſe darkneſs. And if by the heat of the riſing Sun they are diſcuſſed and extenuated, they intimate fair weather; but if they be drawn up altogether into the air, being there congealed by the coldneſs thereof, they therefore become matter of rain very ſuddenly.

And dew is made of a ſmall quantity of thin vapour, which becauſe of the weakneſs of heat, reaches no further than the loweſt region of the Air. And indeed, below the upper part thereof, and being by the cold of a temperate night turned into ſmall drops of water, it ſticks to plants and other things. For the dew is chiefly found on the leaves and flowers of plants, eſpecially where they are ſmooth and thick; and ſometimes alſo on the other parts of them, as alſo upon ſtones. For though it falls alike upon all places below, yet either by reaſon of their frequent pores, and roughneſs, or by their heat, it is drunk up and diſſipated.

Of Dew.

On ſome mountains there is no dew bred; and ſometimes alſo it riſes not above two or three yards, and only the graſs is moiſtened thereby, but things a little higher remain dry. Dew differs therefore from rain only in the paucity of the matter, and the place

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where it is bred, and the weaker heat whereby it is congealed.

Now, dew is generated chiefly in the ſpring and autumn. But ſometimes in the great heat of ſummer, and during the cold in winter, it is not bred; for the heat conſumes the matter, and cold ſuffers not the vapours to be raiſed. Alſo, it is not generated but when the ſky is calm and clear; becauſe when the ſky is troubled and agitated with Winds the vapour is diſpelled, and cannot be congealed into dew. Likewiſe, dew never falls but in the morning and evening; for in the day-time it is conſumed with the Sun's heat, and degenerates into a very thin and light ſpirit. The Chymiſts teach, that dew in ſome places contains in it the moſt ſubtle part of nitre and volatile ſalt, which is contained in the ſurface of the Earth, where it is found.

Of Hoar Froſt.

Hoar froſt doth not differ very much from dew; for hoar froſt is bred moſtly in winter-time, when a thin vapour in a ſmall quantity is lift up from the Earth and cannot riſe high, but by vehment cold of the night it is congealed before it turns to water. Therefore, look what ſnow is in the middle region of the Air, that is hoar froſt in the loweſt region; and what is rain above, is dew below.

CHAP. XL.

Of Earthquakes.

HAVING now ſpoken of theſe motions that are in the Firmament of the Air, by the different meteors that are therein, we come then to conſider

these that are in the Earth, such as earthquakes and fountains. And first as to earthquakes, how it comes to pass that *that* which is the only immoveable and fixed thing in the world, which sustains us and all things on itself, upon which cities are built, doth sometimes reel and stumble.

The Earth is of itself immoveable, nor can be moved by any thing which externally goes about the same, as Winds or Waters. Against the motions of most vehement tempests, the Earth hath formerly stood, and doth still stand immoveable; yet it is moved in earthquakes from somewhat within itself; and the subject of our present inquiry, is to come to the knowledge of the natural cause of the same. But the case is in this, as it is in many other things in the phenomenon of nature, where the immediate cause doth not come under the perception of our senses; and therefore, in our enquiry here, as in many other things, we must endeavour to find out the cause, from considering the effects.

Of Earthquakes.

The effects of earthquakes are wonderful and horrible; for many times it doth not only swallow up single houses, families, or cities, but it overthrows whole nations and regions, and sometimes overwhelms them with ruins; other whiles covers them with a deep gulf, not so much as leaving any appearance of them, so that the Earth is spread over most noble cities, not leaving any mark of their former existence, which happens when by the impulse of the cause, the caverns of the Earth are shaken and fallen in; and sometimes indeed, the cities and houses are not swallowed up in the cavities of the Earth, but the Earth being raised up in a tumour, they fall down flat. Histories are full of such calamitous accidents:

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for in the reign of Tiberius Gaesar, twelve cities of Asia were in one night overthrown; and at another time, the greateſt part of Nicea was overthrown with an earthquake; and alſo, Helice and Buri, were overwhelmed.

Many times alſo, in the Sea, a gulf hath been opened, and Waters ſwallowed up, as rivers on the land, ſo that fiſhes and ſhips ſtood on dry ground; contrary wiſe, many times the Earth ſwelling on high, hath not ſettled again, producing mountains on the land and iſlands in the Sea; whereupon alſo, ſometimes the Sea hath been raiſed aloft like a mountain, and hath afterwards fallen upon the neighbouring lands; for the ſame cauſe, the courſes of rivers have been changed, ſometimes by earthquakes, a tumour or ſwelling of ground being raiſed up in the midſt of the former channel; ſometimes new rivers have broken forth, the ways being opened, through which under ground waters are carried; ſometimes fire and aſhes are caſt out by an earthquake; and ſometimes venemous effluvias break forth, which prove hurtful to man and beaſt. Theſe, and many other effects of earthquakes of a like operation, we have related by hiſtorians that deſcribe their effects.

Now, after we have heard of the overthrows and devaſtations that are made by this phenomena, our enquiries are in ſearch after the knowledge of the natural cauſe of it. Not that we can come to underſtand the time when an earthquake ſhall happen to be, much leſs to prevent its operations when it comes to paſs, for the foreknowledge of the certain time of an earthquake, is altogether unknown by man; neither can all men on Earth, when taken together, prevent or abate its force, when it breaks forth in a moſt

furprifing and awful manner, but rather to revere and adore that divine wifdom and power of God, by which he works, when and where, and how he pleafeth, both in and over all creatures and things.

With, and under thefe preliminaries, we come to fpeak of the caufe of earthquakes. The Earth in which they are bred, is compofed of different ftratas of Earths, minerals, and metals of different forts, in which there is ftore of nitre, and fulphur, efpecially in thofe of the bituminous kind of minerals that are in the Earth; thefe are found on or near its furface, and they are alfo found as far downwards as men have yet dug into the bowels of the Earth; they there meet with bituminous fubftances, in which there is ftore of fulphur and nitre.

Now, the ftrength and effects of fulphureous and nitrous matter, when artificially mixt and compounded together, as in gun-powder, is well known; for it cannot be contained within its proper bounds, but carries all before it while its ftrength continueth, when once it is fet on fire; and yet more, when nitre and fulphur is found, even in its natural fituation, in the bottom of coal-pits and other bituminous pits, if it fhall be kindled and fet on fire there, it operates with a prodigious force, coming up out of the mouths of very deep pits, and blowing up all that comes in its way, efpecially if it have been pent up, and not having a circulation of air, to cool and keep its particles afunder. This is well known to miners, that dig deep into the Earth, who have found its effects to fad experience many times.

And as there are bituminous fubftances found in the Earth, as far as men have hitherto dug into it, we may reafonably expect, that there is much more of

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them further down in the body of the Earth, and ſtore of nitre and ſulphur there; and as this is much more pent up, and kept from the ambient Air, than that which is in the bottom of pits, digged by the hand of man, if this ſhall take fire, it operates with greater ſtrength as being more united in its particles, being not ſo mixt with contrary qualities.

And as in ſome countries, there are more bituminous minerals, found near the ſurface of the Earth than in others, ſo alſo there may be ſome places in the body of the Earth below, where there are a greater quantity of ſulphur and nitre than in others; as alſo, there are ſome countries where theſe fiery ſubſtances may be more expoſed, and ready to take flame than in others, from the rays of the Sun's beams, and other heating cauſes; and when theſe fiery ſubſtances, wherever they are, and external heat unite, they are kindled and break out.

And experience teaches us that there are ſome countries where earthquakes are much more frequent than in others. They generally happen more frequently in thoſe Latitudes that are under the Torrid, than thoſe that are under the Frigid Zones, for they are much ſeldomer felt in Greenland and Lapland, or in Patagonia, than they are in countries under the warmer climates; and even in the warmer climates themſelves, there are ſome countries which are more troubled with their irruptions than others. This may ariſe from the greater plenitude of nitrous and ſulphureous matter that is in the bowels of the Earth, in the places where the earthquakes moſt frequently burſt forth, and the way and manner in which the ground above is diſpoſed, for inlets to external heating cauſes, down to thoſe flameable ſubſtances. And who

knows, but ſulphureous and nitrous matter, may be ſo diſpoſed in other minerals, down in the under ſtratas of the Earth, in ſuch manner, as that it may take flame by flight from its contrary, of Water, or ſome cold quality.

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This ratiocination we propound and deliver, with all deference and ſubmiſſion, on this ſolemn and awful ſubject, as it is ſo indeed, to all thoſe of mankind, that ever had, or have been in thoſe places of the Earth, where earthquakes have made irruptions and devaſtations. And alſo, to all others of mankind, that in ſome degree or other, ſtand expoſed to the ſame calamitous circumſtances. For although, there are ſome times and places, when and where theſe irruptions actually break out more than in others, yet there are in many, if not in all places of the Earth, either near its ſurface or further downwards in its mineral ſtratas, where nitrous and ſulphureous matter lie potentially hid, in bituminous ſubſtances, and theſe are diſpoſed to be inflamed, and ſet a moving by the ſmalleſt touch of external heat, that may meet them; or, they may be ſo couched up in other matter, as to be kindled by light from a contrary quality.

And it is to the power and goodneſs of the moſt good and great God, that all men are indebted, and beholden to, for preſerving the balance, and keeping the elementary contrary qualities in compounded ſubſtances from falling foul of one another, and by a jarring natural conflict that is in them, from ſhaking the Earth, and putting it into diſorder and confuſion; I ſay, it is to the wiſe adminiſtration of the divine providence, that preſerves a due decorum amongſt the elementary qualities, with which the Earth is compoſed, and makes them ſubſervient for the good of the

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whole, and with-holds them from a perpetual ſtruggle and conteſt one with another, which their natures are adapted to, if not properly mixt and proportioned together.

And when the Moſt High, orders and permits this harmony to be broken up in the things of nature, the effects thereof hath a manifeſt relation to the moral world, and of mankind in it, for a warning to all men; and ſometimes, if not at all times, as a puniſhment upon thoſe who fall as victims in thoſe awful irruptions.

The duration of an earthquake is not one and the ſame always, but divers, according as the Earth doth more or leſs reſiſt, or gives an eaſy or difficult paſſage to the ſulphureous and nitrous ſpirits, and winds that break forth, or as the ſpirits themſelves are plentiful or ſcanty; for few ſpirits are ſooner diſcuſſed and ſooner got away, but ſtore of ſpirits abide longer. Alſo, where there is a wide paſſage for them to go out, they go out apace; but when the paſſage is ſhut up, or very narrow, they go out more ſlowly, and continue their buſtling longer.

With the earthquake is joined a noiſe, cauſed by the vehement motion of ſpirits, running to and fro in the caverns of the Earth, and ſmiting againſt the ſides of the Earth. The which noiſe, ſometimes goes before the earthquake, and is a ſign thereof ſuddenly to follow. Sometimes it accompanies the ſame, and it is various, according to the quality of the matter receiving, and the form of the cavities or paſſages through which it goes. And ſome earthquakes have cauſed the ground to tremble continually, for divers days together, others have continued for forty days together; and there have been earthquakes that ſome-

times lafted a year or near two years, and that they have returned at certain times and feafons. CHAP. XL.

And we may be very fure, that the earthquakes bring not only prefent damage, and that the danger is not always in the motion, but there is a greater foretold by them. The Roman hiftorians record, that Rome was never fhaken with an earthquake, but it was a fign of fome event to follow; and very many hiftories teftify that the fame hath happened in other places, and in thefe latter times. And therefore, look what the Romans did of old, who when they felt an earthquake, or heard tidings thereof, they make proclamation that the people fhould keep folemn days for that caufe: much more fhould we, when fuch calamities are prefent or impending, call upon God by prayer. For that which the Romans feared, as Gellius their hiftorian tells us, that leaft by naming of one god inftead of another, they fhould engage the people in a falfe religion, they therefore durft not in their edict, as was their ufual manner, name or appoint to what god the people fhould facrifice, that have we no need to fear. To whom that God is known, who being angry, " The Earth trembles, and the foundations " of the hills are fhaken." 2 Samuel xxii. and 8.

CHAP. XLI.

Of the flowing and running of Rivers, Streams and Fountains.

WE come now here next to fpeak fomewhat of the running and flowing of rivers, ftreams, and fountains, (which are of fo great benefit to the

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Earth) and of the natural cause thereof, from whence they come as to their origin, and where they return in their exit. Let us therefore embrace that short definition which is given us by the preacher, in Ecclestiastes, 1 chapter and 7 verse, as the most comprehensive and compendious, which he gives us in these words. "All the Rivers run into the Sea, yet "the Sea is not full. Unto the place from whence "the rivers come, thither they return again."

But that we may be a little more particular here. The Sea, being the general reservoir and place where the water is kept in store, and chief source from whence moist exhalations and vapours arise in the Air, and the matter of clouds, and the showers of rain that fall down and water the Earth so plentifully, and that by reason of the declivity of hills and mountains, and the height of the Earth above the surface and level of the Sea. They send off the extravagate rains in streams and rivers, which, by reason of their fluidity and natural gravity, they tend downwards and glide along in their several channels until they run forth and fall again into the Sea. But this is not done suddenly and all at once, for the Earth being porous, and having caverns in it, it therefore imbibes the rains when they fall upon it, which, in many countries of the world, serve for a perpetual supply, for streams and rivers, in a greater or smaller degree, from the time of one shower of rain to another.

Of Fountains.

Hence, also a cause may be rendred, why fountains arise on the highest mountains. For there are not only caverns and very porous places in rocky ground, for most mountains are full of rocks, but there are also on the tops of the highest mountains, as is observable, many morasses and quagmires, which receive

and retain the rains that fall from the clouds. And not only that which falls in the more plentiful ſhowers, but likewiſe alſo, that which they receive from the miſts and dews of the night that falls upon them abundantly. And it is further obſervable, that on the ſummits of the mountains, yea, even on the tops of the higheſt of them, the clouds are either more near, or altogether reſt upon them like miſts, which renders the Air upon the mountains more moiſt than it is on the lower grounds. And this moiſt air although not ſo perceptible and plentiful as the ſhowers of rain are, yet it liquidates and waters the mountains, as truly and properly, although in a ſmaller quantity at a time, as the ſhowers of rain do. We indeed ſay, that it is but in a ſmall meaſure and degree at once, yet this moiſture in the clouds upon the mountains is much more frequent and conſtant than the rains are; and it is this conſtancy of the moiſture and ſmallneſs of it at a time, that gives the ſurface of the Earth on the ſummits of the mountains opportunity and convenient time to imbibe and drink in gradually, what falls upon them, without loſing it, by ſending it off in ſtreams ſuddenly, as in time of ſhowers of rain.

So that what the mountains want of moiſture at ſometimes, of the more plentiful ſhowers, they frequently receive at other times more ſparingly from miſts and diſſolving of clouds, that are not formed and turned into rain; for we very frequently ſee, that even in the moiſt dry weather, that there are very many clouds in the Air, which are termed barren. And as the matter of clouds, before they are formed, is imperceptible, ſo the matter of thoſe clouds that do not turn into ſhowers of rain when they are diſ-

ſolved, fall down imperceptibly and inſenſibly upon the Earth and mountains thereof. This, together with what theſe mountains receive and retain of the rains in their moraſſes, pores and cavities, is a conſtant ſupply for water in fountains, and ſmall ſtreams on mountains; and when they are collected together, they ſupply for the more plentiful quantity of water that runs in the rivers, that are in the vallies.

And we further obſerve as to fountains, that there are ſome of them upon the ſummits of little hills or high rocks, which we obſerve in ſome places, which ſtand towering and jutting upwards, in the midſt of champain grounds, or otherwiſe, which are not of a ſufficient breadth and largeneſs of dimenſions, for receiving and retaining rains that fall from the clouds, for the ſupply of conſtant ſprings; and yet there are fountains on their tops, which conſtantly flow out. And we obſerve alſo, that there are in their neighbourhood, much higher mountains, and of larger dimenſions, that have cavities and moraſſes upon them, for receiving and retaining of water that comes from the clouds, when they pour down in rains, or diſſolve more gently in miſts. Theſe high mountains are as a repoſitory for water, to ſupply the little hills withall.

And as the Lord did not create the Earth in vain, but to be inhabited by men and other creatures that are upon it, ſo he hath granted a ſupply of all the neceſſaries of life unto them, even in every place of the Earth, either more ſparingly, or more plentifully. And we cannot account better for the fountains that are on the ſummits of ſome few particular little towering hilly rocks that are in ſome places, but that the water is conveyed to them below ground, from the higher neighbouring mountains, as in leaden pipes

through the caverns of the Earth, and by the weight and preſſure of the water at the ſource on the higher riſing mountains, it makes the water to circulate in theſe caverns, and aſcend to the top of the neighbouring lower little hilly rocks, and there to flow out.

Having given the natural cauſe of the flowing, order, manner, continuance and circulation of fountains, ſtreams and rivers, that they have their origin from the ſea, and that the rivers make their exit in, and fall into the ſea. We ſhall end our deſcription of fountains and rivers, where we began. "All the rivers "run into the ſea, yet the ſea is not full: unto the "place from whence the rivers come, thither they "return again."

We ſee therefore, that it is not the ſame identical water that is in the fountains and rivers, that evaporates into the clouds, and falls down again and ſupplies their defects; but it is water that riſes out of and exhales from the Sea, moſtly; that is, the matter of clouds and rain that moiſtens the Earth, and that cauſeth it to yield and ſend forth fountains, ſtreams and rivers.

And although the water in the Sea, be of a ſaltiſh and briniſh taſte, when it exhales up into the Air, in ſuch ſmall particles, the Air purifies and extracts the ſaline quality from it, when it is metamorphoſed into ſteams and vapours, and the clouds upon the Earth is quite freſh, and free from all brackiſhneſs in the taſte and quality, which by the bye ſheweth the benefit of one Element for the purifying and refining another.

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Of the different Tides by the ebbing and flowing of the Sea.

HAVING now ſpoken of, and explained thoſe various motions that are in the Elements, on the ſurface of the Earth; ſuch as exhalations, fountains, ſtreams and rivers, and thoſe that are in the body of the Earth itſelf, by the earthquakes. And that we may come to finiſh our deſcriptions of the moſt remarkable movements that are on the terraqueous Globe; we come in the laſt place, to ſpeak ſomewhat of the tides that are made by the ebbing and flowing of the Sea. And as in the diſquiſition of this ſubject, there is ſomething plain and evident, yet there are others in it, that are very difficult and abſtruſe, as to the order of tides there. For obſervations teſtify, that the high Seas, on moſt main ſhores, riſe and fall according to the courſe of the Moon; and that the flux and reflux of water alternately continue about the ſpace of ſix hours and twelve minutes time together. And in one compleat circulation of the Moon about the Earth, there are two tides, and alſo two ebbings of the Sea.

There are alſo obſervations made, which have much difficulted ſome men to underſtand how it comes to paſs; for there are ſeas that waſh ſome particular ſhores, that do not obſerve this general rule, in their riſing and falling; for in ſome places, it flows ſeven hours and ebbs five; in others, it flows four hours and ebbs eight. And in the bay of Cochin-China,

or Tonquin, there is but one flood and one ebb in twenty four hours. And further, even almoſt in the ſame ſhores, that it is high water at Calcutta when the Moon is full, and at the ſhores of the river Indus when the Moon is new, in which variety, nevertheleſs there is this regularity, that the ebbing and flowing together, laſt but twelve hours and twenty four minutes time; except in one particular bay or two, as we have yet heard of, there is ſome variation. All theſe things come to be better underſtood when more fully explained. CHAP. XLII.

Having given theſe general obſervations, of the evolution in the riſing and falling of the waters of the Sea, it requires ſome time in the diſcuſſion, to treat properly upon the natural cauſe thereof; for the motion and agitation of any inanimate body whatſoever proceeds either from a power and principle of motion implanted in itſelf in the beginning, by the all Wiſe Creator, or by the impulſive and attractive force of a natural body operating upon it, and cauſing it to move, or the co-operation of both together.

As to the firſt of theſe, that there may be a power and principle implanted in the body of the waters that are in the Sea, to riſe a little upward in ſome places above their proper level, in order to accelerate their motion and circulation into other places for their more general commodity, appears from hence, that as there is a power of attraction implanted in ſome bodies for operating upon, and moving other bodies, ſo there are many bodies in nature, that the Creator hath endued with a principle of motion inherent in themſelves, by which they continually move and circulate in the material expanſe.

And that the waters of the Sea are put and kept

CHAP. XLII. in perpetual motion, for the more general commodity and benefit of mankind on Earth, is neceſſary to preſerve them from a general ſtagnation, and corrupting of their quality, and ſo ſending forth noxious ſteams and vapours that might be hurtful to men and other creatures; but this conſtant agitation and motion of the waters of the Sea by wind and tides, this opens their particles, and makes them more porous, and ſo expoſes them to the vanning of the Air, and receiving aſſiſtance from the purifying quality thereof; for that the water receives and preſerves much of its purity from the Air, we have before deſcribed. And in alluſion to this, we here tranſcribe what is ſaid by the prophet Iſaiah, lvii. and 20. "That the wicked are like "the troubled Sea, when it cannot reſt, whoſe waters "caſt up mire and dirt." And it is certain that the waters of the Sea may be endued with a natural propenſity for moving and purifying of themſelves.

And ſecondly, that the waters of the Sea may be moved by the impulſive and attractive force of other bodies, operating upon it and cauſing it to move; for there is a power of attraction implanted in ſome bodies for operating upon others of a like kind or quality, and drawing them towards or after themſelves. And that there is ſomething of this in the preſent caſe, appears from this, that there is a great affinity and correſpondence betwixt the general movements of the Sea, and thoſe of the Moon; for when the Moon approaches the Meridian of any place, the ſwelling and flowing of the Sea on all free and main ſhores, follows on apace; and when ſhe declines and emerges upon the Horizon of a place, they upon the coaſts of that place have preſently ebb water. And further, when the Moon comes upon the Equinoctial,

the water flows most in from the two Poles, and makes highest tides in most climates. CHAP. XLII.

And it is yet still further observable, that the high water and spring tides fall in with the new and full Moons, and the neap tides with the quarters, which are partly occasioned by the attractive force of the Sun, in the new and full, conspiring with the attraction of the Moon, and producing a tide by their united forces. Whereas in the quarters, the Sun raises the water where the Moon depresses it; and he depresses it where the Moon raises it, so that these tides are partly made by the difference of their attractions. And that the Moon hath more force than the Sun, in this case, may proceed from this; that she is nearer to the Earth than the Sun is, and not of such a hot and dry quality. So the tides and ebbs, are observed to have certain affinity and connection with the conjunctions, oppositions, and squares, or angles of the Sun and Moon. When they are in the conjunction in the Equinoctial, there are the highest tides; and when they are in opposite Tropics, then there is the lowest tides; and when the Sun and Moon are in a square position, or in a mean between these extremes, then the water rises to a middle extent, being neither so high as in spring tides, nor so low as in neap tides. This general correspondence of the movement of the great abyss of waters in the Sea, with the different aspects and positions of the two luminaries in the Heavens, sheweth in part the connection and benefit that this terraqueous Globe receives from the heavenly bodies.

We have here described the affinity and likeness, that there is between the most general motions of the Sea, and that of the Sun and Moon in the Heavens;

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but that all the different and opposite movements of the Sea depends solely and intirely upon the attraction of the Moon or Sun, or even both together, we have these exceptions. It is very true indeed, when the Moon is in the Zenith or Meridian above the Horizon, the water swells, or raises itself into an heap, and we have a tide; but it is as true, that when the Moon is in the Nadir or Meridian below the Horizon, the water is poured abroad plentifully, and we have a tide also; and this is the case whatever situation the Moon may be in with respect to the Sun; whether in conjunction, opposition, or in a square.

As in the case of the first tide, it would seem to depend upon the attraction of the Moon, and that sympathy that is betwixt her and the waters of the Sea, in contracting them so much, and drawing them nearer to herself. But in the case of the other tide, it would rather proceed from antipathy and repugnancy, between the Moon and the waters of the Sea, in impelling them, and forcing them to a greater distance from her.

We shall further observe, that the waters of the Sea, if not affected by an external cause, or otherwise appointed, would naturally form a perfect sphere. It then comes to be considered, how the great abyss of waters in the Sea comes at all to be moved, either less or more; for when the Water in the Sea is considered separately by itself, it is a more ponderous Element than that of the Air, and therefore hath a natural appearance to gravitate and press itself downwards to the centre of the Earth, and so to rest in that situation.

And when we consider also, the force of attraction that is in the Moon or Sun, in this case by themselves, abstractly, we see that their main and chief force

consisteth in their being moved diurnally around the Earth in their circuits; but when we consider their operations upon the Earth or Water, as in the case of a certain particular, we see that they cannot attract an ounce of ponderous Earth together, nor yet raise a pound weight of dense water by itself perpendicularly upwards; therefore, when we consider the water, and these two luminous bodies separately, the one tends downwards to the centre of the Earth, and the other circularly around the Earth. CHAP. XLII.

And therefore in this case, they must be viewed and considered, as conjoined in this movement. And in this, as in all other cases, we must have recourse to the wisdom, power and providence of God, for that most wise connection and affinity that there is amongst all the works of nature; and for that affection and influence that is in the Heavenly bodies, for aiding and assisting the Earth in sending forth her effluviums, and all her elementary movements. We have before described that the Earth and Water cannot lift up themselves, and that the Sun or Moon, in a certain particular, cannot draw up an ounce of ponderous Earth together, or even a pound weight of dense water; but when viewed under this connection, that is, amongst the divine works, these luminous bodies can raise very great and weighty matter above the surface of the Earth, and raise the waters of the Sea, under a considerable part of a whole Hemisphere, above their proper level.

As for instance, by and through this connection and affinity the Heavenly bodies, particularly the Sun, in process of time can raise and draw up from and above the surface of the Earth a vegetative live growing tree, of many tuns weight, perpendicularly

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We ſhall alſo mention two other inſtances of the power that proceeds from the affinity and connection that is between the heavenly bodies and the terraqueous gobe, as in the caſe of the extenſive and ponderous clouds, that are raiſed aloft in the Air. And when they are ſuddenly condenſed, or fall down in water-ſpouts, as ſometimes in warm climates, within the Tropics, they overthrow towns and cities, and whatever comes in their way; and alſo in the caſe of great and boiſterous winds which proceed from the general and complex body of the Earth. As to the matter of them, when theſe come to blow in their greateſt extent and force, they upon the land overthrow houſes, and throw up trees by the roots; and on the Sea, they raiſe mighty billows and waves one after another, in the form of hills and mountains. Theſe mighty operations, as hath been obſerved, do not proceed from the Earth alone, neither altogether alone from the matter contained in the bodies of the luminaries in the Heavens, but from the united influence of compounded matter, of the terraqueous Globe, as being indued with a power and natural faculty for yielding ſteams and vapours of exhalations hot and dry, or more moiſt; and from the attractive force, and influences of the Heavenly bodies co-

operating with the Earth, and aiding her in theſe various operations.

Now after having conſidered that connection and relation, that is between the Earth and theſe bodies in the Heavens that circulate about it, and the aſſiſtance that the Earth receives from them in ſending forth her various effluvia, that riſe upwards in the air above her ſurface, we come more particularly to conſider that affinity and harmony that there is between the Sea, as to the motion and moving of its various ebbings and flowings, and that of the Moon in her circulations and different poſitions. In this indeed there is a great ſimilarity and likeneſs, yet the various tides do not come up with, and in all places keep time with that of the Moon; for the higheſt ſpring tides are not preciſely on the new and full Moons, nor the neap tides on the quarters, but generally they are the third tides after them, and ſometimes latter; and by reaſon of interpoſing continents in ſome places, it is obſerved, that in the open ocean the time of high water is not at the time of the Moon's appulſe to the Meridian, but always ſome hours after it, as is obſerved on all the weſt coaſts of Europe and Africa, and the weſt ſide of America, where a ſouth weſt Moon makes high water.

After what hath been ſaid, we here obſerve, that it is expedient to aſcribe theſe periodical motions of the Sea, to the creating power of God, and his conſtant and perpetual providence, that gives laws to, and over-rules and governs all inanimate bodies and matter whatſoever, and the natural ſituation and diſpoſition that he hath given to the waters of the Sea, both to move and be moved. And under this ſupreme and ſalutary view, it is no more to ſee the

waters of the Sea have a conſtant and periodical motion, than to take cogniſance of a ſtar in the Heavens that hath a perpetual motion there. And that theſe waters of the Sea, are put and kept in conſtant motion for the more commodity and benefit of mankind, and to preſerve them from ſtagnation and corrupting in their quality; and to prevent them from ſending forth noxious evaporations that might be hurtful to men and other creatures, and have laws given them to obſerve a concomitant and correſpondent motion, with and after that of the Moon.

And in order to this, that we may come to ſome conception of the manner how this motion comes to paſs, according to the extent of knowledge that is in the human mind, we are to underſtand that the Earth and Sea, when created, were compoſed together in the form of a globe or ſphere, as to their general frame and faſhion, only with this difference; as to the dry land, that it towereth and ſtandeth upwards in ſome places in hills and mountains, and alſo in other places there are intervening plains and vallies, and in this reſpect the Earth is not a perfect ſphere.

And alſo, as to the Sea, by the law of its creation, it doth not form a perfect and compleat ſphere, but is to be underſtood as very near the form of a ſphere, whoſe diameter is a little longer the one way more than that of the other. And this liquid ſphere being ſeveral feet, or a few yards of meaſure more in length than in breadth; and the Sea being underſtood in this figure, we may alſo conſider that this oblong ſphere, or ſpheroidical figure of the Sea, makes as it were a compleat revolution and circulation about its axis in a day or 25 hours.

And to aſſiſt our conceptions in this matter, let us ſuppoſe that the Earth were covered all over with water very deep, in that figure as we have ſaid, this diurnal revolution and circulation of the ſea, would move about in an uniform and imperceptible courſe. But this not being the caſe, for the ſea being lower than the land, and there are very large intervening continents that lie acroſs to this general revolution and rotation of the ſea, which occaſions and cauſes many other librations of the water beſides this.

For the more general movement and preſſure of the ſea being from eaſt to weſt, according to the courſe of the Moon, and the other heavenly Bodies, and the continents of the earth ſtretching out from north to ſouth, although that they extend not near the Poles, yet they interfere with this, in ſome meaſure, which cauſes various librations in different ſeas, ſtraits, and bays; and occaſions, in ſome ſenſe, that the general revolution of, and longeſt diameter of the ſea, is not directed towards the Moon in her courſe, but is ſome little behind her in it.

Now as we underſtand, this law for a diurnal revolution was given to the ſea itſelf, by the Creator, in the beginning of the world, as well as that diurnal revolution which the Moon hath in her courſe. And as the Sun and Moon were appointed to rule the day and the night, and to be for ſigns and ſeaſons, and to communicate light and heat to the earth, and thereby to be ſerviceable to it; ſo with reſpect to the Sea, they are for ſigns and ſeaſons in their different poſitions, as to its periodical motions, and not altogether and alone, as the cauſes thereof. For that which doth not lift up a pint of ſolid water together out of a ſtanding lake or pool, cannot be ſuppoſed to raiſe up

CHAP. XLII. a whole ocean, if otherwise it were disposed to rest in its place.

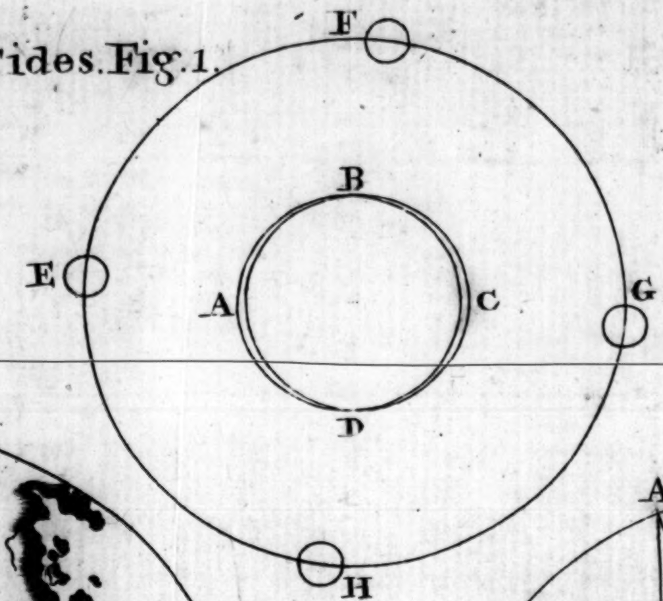
But the Sea of itself being disposed and appointed to move, these serene rays of the Moon, together also with the more warm influences of the Sun, assist in accelerating these regular and perpetual motions of the Sea. And that which cannot be done by one cause, is wrought by concurring powers and influences. Now, if we take and consider this description of the flowing and ebbing of the sea, together with its concurring causes, there is no more mystery in it, than there is in the rest of the works of the divine power, which are all wonderful and to be admired.

For he that appointed the Moon her way in the Firmament of Heaven, also gave a law to the Sea in this diurnal revolution. And the Sun and Moon were ordained for signs, and regulating the seasons thereof in their courses, between which there is a great similarity and affinity. And as there is a divine interposition in this case, we are not to conceive that the waters of the Sea are simply under a natural necessity to form and keep themselves in a perfect spherical body together. For when sovereign power takes place, all such conceptions are improper. For the Lord hath broke up for the Sea its decreed place, and hath set bars and doors; and hath said, "Hitherto shalt thou come, and no further; and here "shall thy proud waves be stayed."

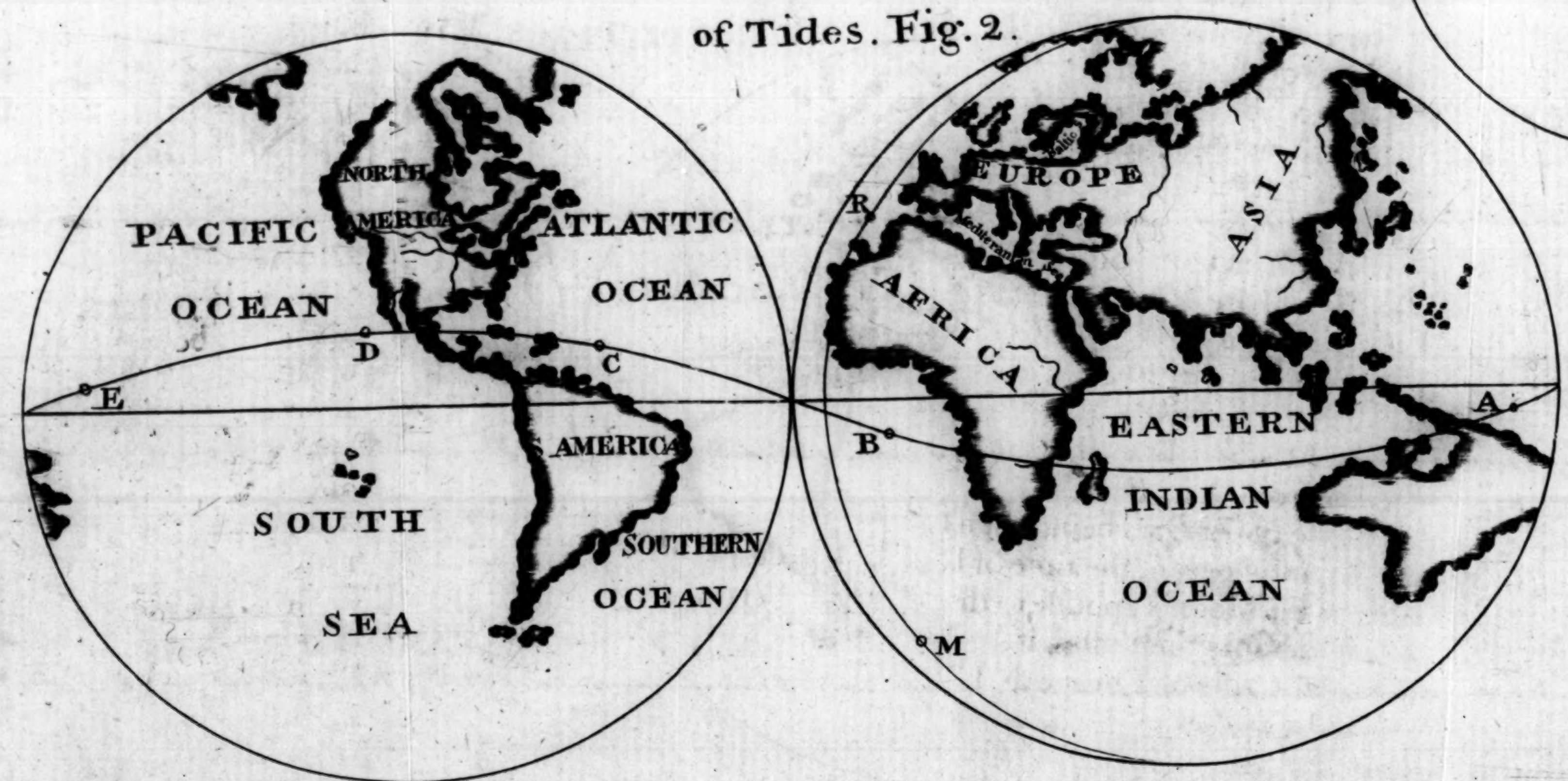
Plate 23. Fig. 1. Of Tides. Figure 1st. And here to represent the uniform motion of the waters of the Sea, let ABCD be the spheroidical figure of the Sea, and EFGH the orbit of the Moon. When the Moon is in E, there is a tide and high water in A and C; and when the Moon has shifted her situation from E to F, then there is a

PLATE XXIII.

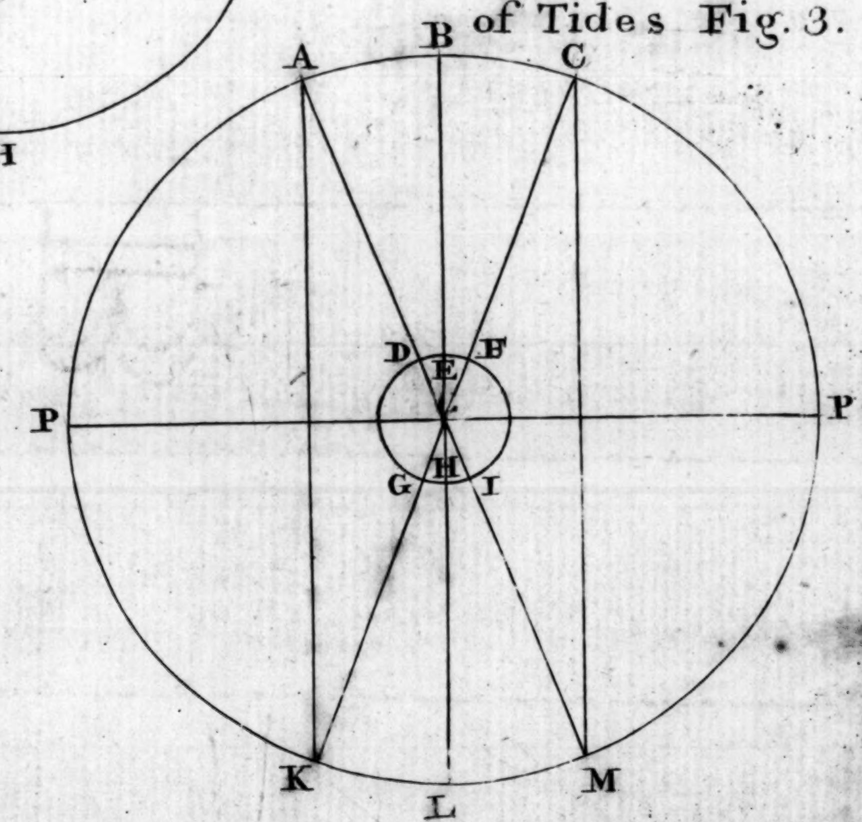
of Tides. Fig. 1.



of Tides. Fig. 2.



of Tides Fig. 3.



tide in B and D; and that which before was high water, now becomes ebb water. And again, when the Moon has come from F to G, there is a tide in C and A, and B and D become ebb water. Afterwards when the Moon has removed from G to H, then again D and B become high water, and C and A in their turn are ebb water. And when the Moon has further removed from H to E, then again A and C become high water as before, and D and B is low water. And thus as the Moon is in the Meridian or Horizon of any place, there is alternatively a tide or ebb water in that place. And this would very near be the caſe, with reſpect to the diurnal revolution of the water of the Sea, if there were not intervening continents to obſtruct its courſe.

And as we have given a deſcription of the general movement of the Sea in its diurnal revolution about from eaſt to weſt, we ſhall next give a repreſentation of the obſtructions or principal hinderances that it meets with in its general courſe, as in figure 2d. Let the Moon be in the Zodiac line at A above the Eaſtern ocean, to the eaſt of New-Guinea, and the ſea is there high water, very near under the Meridian of the Moon. But when the Moon has ſhifted her ſtation from A to B, above the Ethiopic ocean, and weſt ſide of Africa, being then above the eaſt ſide of the Atlantic ocean, the time of high water is not at the time of the Moon's appulſe to the Meridian, but always a conſiderable time after it, as is obſervable upon all the weſt coaſts of Europe and Africa. The cauſe of this is by reaſon of the interpoſing continents of Europe and Africa, which obſtruct the progreſſive motion of the Sea from eaſt to weſt; ſo that before the high water have time to move out of the north-eaſt

Plate 23. Fig. 2. Of Tides.

Sea, by the north cape of Lapland in Europe, and out of the Indian ſea and Eaſtern ocean, by the point of CapeBona on the ſouth of Africa, and make full tides upon the European and African weſtern coaſts, it requires two hours leſs or more (according to the different ſituation of places) latter than the Moon's Meridian altitude.

And next when the Moon moves from B to C, and is above the weſt ſide of the Atlantic ocean, and eaſt coaſt of America, the high water alongſt that coaſt comes much nearer up with, and correſponds with the Meridian of the Moon. The reaſon of this is, that *that* large ocean is not interrupted in its progreſſive motion to the weſt, from the coaſts of Europe and Africa to the American ſhores, with any large intervening lands, which occaſions that the tides alongſt that coaſt, come more up with, and keep nearer the time of the Moon.

And further, when the Moon has removed from C to D, and is above the weſt coaſt of America, and eaſt ſide of the Pacific ocean, the time of the high water there is not at the time of the Moon's Meridian appulſe, but always ſome hours latter. The cauſe of the floods being latter upon theſe coaſts is by reaſon of the intervening extenſive continent of America, which ſtretcheth out from north to ſouth, and before the high water makes its egreſs from the Atlantic ocean, by the end of Cape Dudley in North America, and by the point of Cape Horn in South America, or otherwiſe into the Pacific ocean, the Moon is ſouth-weſt before there is a tide and high water on the weſt coaſt of America.

And alſo further, when the Moon has proceeded on in her courſe from D to E over the vaſt Pacific

ocean, and is above the Isles of Berbudas, the high water there comes forwards and draws nearer under the Meridian of the Moon. This spacious Sea not being interrupted at all with any considerable tracts of land in its progressive movement, which gives the Pacific ocean the more liberty to keep time with the Moon. So thus the tides and high water of the Sea, when interrupted by interposing continents in some places, do not keep time with, and come under the meridian of the Moon, but are after it a considerable space, in their general and diurnal motion; and where they are free from these obstructions, they keep nearer under the Moon's Meridian. CHAP. XLII.

Having given a description of the general movement of the Sea, and the obstructions that it meets with, and the times of high water upon the free and main coasts of the Earth, and the Islands that are stationed in the open ocean, we come next to consider the order of tides in some particular bays. The tides in the bay of Cochin China, or Tonquin, are the most extraordinary of any we have heard of, as differing from all others, in the times that they observe. In this bay there is but one flood and one ebb in twenty four hours, and twice in each month, viz. when the Moon is near the Equinoctial there is no tide, but the waters are stagnant; but with the Moon's declination there begins to be a tide, which is greatest when she is in the Tropical signs, only with this difference, that when the Moon is to the northwards of the Equinoctial, it flows when she is above the Earth, and ebbs when she is under it, so as to make high water at the Moon's setting, and low water at the Moon's rising. But on the contrary, the Moon being to the southward it is high water at

her riſing, and low water at her ſetting, it ebbing all the time ſhe is above the horizon, as may be ſeen more at length in the Philoſophical Tranſactions No. 162.

We ſhall here inſert what is ſaid upon theſe tides by Sir Iſaac Newton. The cauſe of this odd appearance is propoſed by Sir Iſaac, to be from the concurrence of two tides, the one propagated in ſix hours out of the great South Sea, alongſt the coaſt of China; the other out of the Indian Sea, from between the iſlands, in twelve hours, along the coaſt of Malacca and Cambodia. The one of theſe tides being produced in north Latitude, is greateſt when the Moon, being to the north of the Equator, is above the Earth; and the leſs when ſhe is under the Earth. The other of them which is propagated from the Eaſtern ocean, being raiſed in ſouth Latitude, is greateſt when the Moon, declining to the ſouth, is above the Earth; and leſs when ſhe is under the Earth. So that of theſe tides alternatively greater and leſſer, there comes ſucceſſively two of the greater, and two of the leſſer together, every day. And the high water falls always between the times of the arrival of the two greater floods, and the low water between the arrival of the two leſſer floods. And the Moon coming to the Equinoctial, and the alternate floods becoming equal, the tide ceaſes, and the water ſtagnates. But when ſhe has paſſed to the other ſide of the Equator, thoſe floods which in the former order were the leaſt, now becoming the greateſt. That which before was the time of high water, now becomes the time of low water: and the reverſe.

After what Sir Iſaac has ſaid, we have only further to obſerve (as we have before taken notice of) that the tides are higheſt in this bay, when the Moon, in

the northern Signs, is above the Earth; and leaſt when ſhe is under the Earth, and moves in the ſouthern Signs. And according to the natural ſituation of this bay of Cochin China, there is always one of theſe leaſt tides in it; ſo that the difference betwixt the high and low water in this bay, proceeds only from the difference that is between the greateſt and leaſt of theſe tides, And as this bay is adjoining to, and receives its tides from the Formoſan Sea, which are ſix hours earlier; and as theſe tides are intercepted from iſſuing out of the bay, according to the time of the tides, in open Seas, by reaſon that the tides and high water in the Eaſtern ocean, and Indian ſea, are ſix hours latter. And the natural egreſs of the tides, out of the bay of Cochin China, is into the Indian ocean. For the general courſe of the tides moves to the weſt, according to the courſe of the Moon, as hath been ſaid. And this bay lieth in ſuch a natural ſituation, as not to get clear of its high water, until the tides draw off from the Indian ſeas. But this will be better underſtood by what is afterwards ſaid.

And as the Sea being ſomewhat of a ſpheroidical figure, and as its high water or tides make a complete circulation round from eaſt to weſt, in the ſpace of a day or 25 hours. And when theſe floods come periodically upon the main coaſts of any continent, if they did not enter the ſtraights and bays thereof, the Sea would ſtand towering perpendicularly upwards, like a wall at the entrance of bays, and at the foot of rivers, and would be from 8 to 16 feet high above the level of long and ſtraight bays, and the foot of navigable rivers, where they make their exit into the Sea, on all the weſt coaſts of any continents or iſlands. Therefore, when the high water, or theſe apparent

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floods come alongſt the coaſts of theſe continents, as has been ſaid, the Sea purſues both its occidental courſe, and preſerves its ſpheroidical or oval figure. For which cauſe, when the tides come alongſt the ſide of the weſtern main coaſts of any lands, the high water, to maintain this oval figure, makes its way into the lower bays, ſtraights, and ſhores, and in the foot of navigable rivers, and even into theſe on the weſtern coaſts that have their direction in the continent, towards the eaſt, as well as thoſe on the eaſtern coaſts, that have their direction towards the weſt. This is the caſe in all known places of the world, and particularly with the many, and of all others, this is obſervable in the Sound of Denmark, that leadeth into the Baltic, and at the ſtraights of Gibraltar, that goeth into the Mediterranean Sea. Both theſe laſt mentioned ſtraights and ſeas, to which they communicate, have their direction to the eaſtward from the main ocean.

This, in ſome meaſure, manifeſts that the Sea is not wholly and altogether moved by the ſpecific virtue of the Moon, (although ſhe be for a manifeſt concomitant ſign of the way and manner of this diurnal movement, as to the general body of the maſs of water in the Sea.) For the high tides, when they come on the coaſts of the main ocean, make their way into the lower ſtraights, bays, and rivers, towards the Eaſt, with equal freedom as towards the weſt, and glide along the ſtraights of narrow ſeas, and in the end of navigable rivers, in a direction diametrically contrary to the courſe of the Moon. And this ſhews that the tides, and high water of the Sea, in their progreſſive motion weſtwards, always preſerve their oval figure, as in figure 1ſt, except when interpoſing continents intervene.

Now this ſpheroidical, or oval figure of the Sea, in its diurnal revolution, meets with interpoſing continents, that have very curve limits or coaſts, together with many iſlands of different dimenſions and ſituations; and in and amongſt theſe, there are many various and different bays, ſtraights, and narrow ſeas, with different manner of inlets to them. So that the ſea, in preſerving its ſpheroidical figure when proceeding on in its occidental courſe, muſt make tides as diverſly, both as to their time and order, as the bays, ſtraights, ſeas, and inlets are different and various. This neceſſarily proceeds from the deſignation of things, and the laws by which that Element operates.

And when a Philoſopher would render a reaſon, why the high water in any particular bay, ſtraight, or narrow ſea, keeps not time with the general law of tides in the main ocean, he muſt firſt thoroughly underſtand the terreſtrial Globe, in the natural ſituation of land and water of the Sea, and then conſider the ſituation of theſe bays, ſtraights, or narrow ſeas, in their diſtance from the main and open ocean; and the way and manner how the water comes in, or iſſues out of them. And as to this, there is a conſiderable variety among them; for in ſome, the water iſſues out by the ſame channel by which it came into them; and amongſt thoſe of this ſort, there are ſeas that are much longer than others; and the further any ſea extends out from the main ocean, it requires the more time before the water make way to its head. And when once water is put in motion, the force that is impelled upon it carries it forward for ſome ſpace of time, before it makes its libration and return. And further as to this kind of ſeas, the inlets to ſome of

CHAP. XLII. them are very open and broad, to others of them the entry is very narrow and ſtrait, which makes a conſiderable difference both as to the degree and quantity of the tide, and alſo as to the time thereof.

And again further, there are another kind of ſeas, or bays, where the water enters into them by one paſſage, and iſſues out from them by another; they receiving in their tides from one main and open ocean, and emptying it out again into another. And as to the bays, or narrow ſeas of this ſort, ſome are ſtraiter where the water enters into them, and broader where it iſſues out. And other ſome of them, have the entry into them broad, and narrow where the water goeth out. And ſome bays the entry into them, and out from them, is more nearly equal. And moreover, there are ſome ſmall ſeas or bays where the water paſſes into them by two different inlets, and iſſues out from them by the ſame paſſages. And amongſt all theſe the natural ſituation of the ſmall ſeas or bays is to be conſidered, and alſo the main ocean from which they receive the high water, and the ocean into which they empty the water again. All theſe things are ſo various, by reaſon of the different manner of the interpoſing continents and coaſts, which neceſſarily makes a difference as to the order and time of tides, in thoſe places, from the general rule and law of tides, as to the time thereof, in the open and main ſeas.

For though the tides in the great depth, or abyſs of waters of the ſea, make a circular or ſpherical revolution about, in near the ſpace of one day; yet thoſe extravaſated waters, that make their excurſions from the main ſeas into the curve bays, or long extended channels and ſtraits, cannot make their librations in-

ſtantaneouſly and all at once; but this neceſſarily muſt require ſome time for the motion of the water of the main ſea, to glide in upon theſe ſhallow places and bottoms, and to make its way off them again, into the main ſea.

After what is here ſaid, it may be required, how it comes to paſs that the general revolution of tides, round about in the ſpherical body of water of the ſea, in the ſpace of one day and 48 minutes, is not more obſervable, by making apparent currents on its ſurface. As to this, it is manifeſt that the waters which make excurſions into the long ſtraits and ſhallows, have very evident and ſenſible currents in their librations in, upon, and out from theſe ſhallow ſtraits; becauſe the tides themſelves bear an evident proportionable bulk to the other waters in theſe ſhallow places, which makes the motion of the tides to be the more ſenſible there, and this, according to the ſhallowneſs of the bottoms over which they paſs and repaſs. But the tides upon the ſurface of the main body of the waters in the ſea have no ſenſible egreſs that can be diſcerned; for a few feet of elevation of water, in the very great depths of the ſea, where in ſome places it may be many hundred fathoms deep, and in other places many thouſands of fathoms, as to its depth of water. A tide therefore, in thoſe places, bears but a ſmall proportion, in reſpect to the great deep below. And when water in any place is conſidered as an united body, whoſe particles in ſome meaſure adhere together, and alſo where there is due freedom, they have a degree of elaſticity. This occaſions that the tides, on the main body of the water in the ſea, have no ſenſible motion, but make their circular revolution imperceptibly without being diſcerned.

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Hitherto we have confidered the affections of tides in the ocean, and in particular bays, and fmall feas or ftraits, as to their diurnal revolution. We come next to defcribe the manner of tides in their monthly and annual periods. As to the monthly periods of tides, there are two of the greater, and two of the leffer during the time of every Moon. The two greater tides are produced in a day or two after the new and full Moons: they being generally the third tides after them. And the leffer tides are alfo produced in the fame fpace of time, after the quarters. And fecondly, as to the annual tides, there are two of them remarkably higher than all the others every year. And thefe very higheft fpring tides are found to be before the vernal, and after the autumnal Equinox; viz. in the months of February and October, fome two or three tides after the new or full moons; and the fubfequent neap tides as long after the quarters.

Plate 23. Fig. 3. Of Tides.

Having now confidered the time, and order of the tides, as they are produced once a day, or in a month, and in a year, we come now to fhew how they affect particular places, in refpect of their different latitudes. And this will be eafily underftood by the annexed figure. As in the 3d figure of tides, Let DFIG reprefent the fpherical or fpheroidical body of water in the fea, and PP its Poles, and BL the Equinoctial line drawn through EH, and ACMK any one Meridian of the Moon. And let the Moon be in the Equinoctial at B in the Zenith above E, it is then high water at E, and at the fame time it is then alfo equally high water at H, or very nearly fo. But in twelve hours time, when the Moon has revolved in her courfe till fhe come under the Earth at L, in the Nadir

Meridian below H, it is then high water at H, and then again E becomes alſo high water as before. Hence we ſee, that the tides are then both higheſt and equal at the Equinox. And at the ſame time, in the two parallels, of the Equator that are on the north and ſouth ſides thereof, the tides are equal, and the ebbs are ſo likewiſe, viz. at FI and GD; but as the Moon declines from the Equator, the alternate tides vary as to their height. For when the Moon is come into the northern Signs, and is in the north Tropic at C, in the Zenith of F, then it is high water at F, under the Moon, and in the oppoſite parallel at G, on the other ſide of the Equator. And when the Moon is in this poſition, the neap tides are found to be at D and I, in an angle poſition of the Equinox. And in twelve hours time when the Moon has removed from the Zenith of F, above the Earth, and is come to M in the Nadir at I, and is in the Meridian under the Earth, in this caſe, the higheſt tides are found to be at I and D, the higheſt water of the tide directing its courſe under the Moon, and to the oppoſite point. For which cauſe G and F in the angle, and oppoſite places, have in their turn a neap tide, ſo that as the Moon makes her way into the northern Signs, the floods vary gradually as to their degree of height alternatively. And when ſhe is in the north Tropic, the high tides and neaps differ moſt; the higheſt floods, being always when the Moon is in the Meridian above the Earth, and the neaps when ſhe is in the Nadir in this part of the world.

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But when the Moon has returned in her courſe, and declined from the Equator into the ſouthern Signs, to the ſouth Tropic, and is at A, then D and I have their higheſt tides, and G and F their neap tides.

CHAP. XLII. And twelve hours afterward when ſhe is come to K, then G and F have their high floods, and I and D their neaps. Whence it is that the Moon being in the northern Signs, they that live on the north ſide of the Equator, have their greateſt tides in theſe ſeas, and obſerve them on the coaſts, when ſhe is in the Meridian above the Earth; and the neap tides, when ſhe is in the Meridian under the Earth. And when the Moon is in the ſouthern Signs, theſe that are on the ſouth of the Equator, likewiſe obſerve the higheſt floods on thoſe coaſts when the Moon is in the Meridian above the Earth; and their neap tides when ſhe is under it. But when the Moon is in the ſouthern Signs, it is the reverſe way in northern latitudes. For a meridianal Moon is a ſign of a neap tide when ſhe is above the Earth, and of the greater tide when ſhe is in the Nadir.

What we have here ſaid with reſpect to tides, may be uſefully applied to particular caſes, when the diurnal movement of the tides to the weſtward is underſtood; and the natural ſituation of bays, ſtraights and narrow ſeas, with the way and manner how the water enters in, and iſſues out from them; whether it be by one or two different paſſages, or if it enters by one paſſage, and goes out by another; together with the ſituation of the main ſeas from whence the water comes into them, or makes its egreſs off from them; and alſo the latitude in which they particularly are. And moreover, theſe variations that are made by the monthly and annual tides is to be conſidered, as we have before deſcribed, and of which the Sun and Moon are evident ſigns and tokens. We ſay, when theſe things are all duely conſidered, and underſtood, the time and manner of tides, in any particular bay,

ſtraight, or coaſt, may come to be known and explained. CHAP. XLII.

After having ſaid ſo much concerning the order and time of tides, we ſhall here inſert what is ſaid by Sir Iſaac, in his Philoſophic Natural Principles. As to his theory of the tides, he was of opinion, that the Sun and Moon have a like principle of gravitation towards their centres; and that the Earth is within the activity of their attraction; and that the diurnal movement of the Sea is cauſed by the Moon ſhifting her poſitions, as ſhe turns round the Earth once a day; and that the tide ſhifts with her, occaſioning thereby the two floods, and two ebbs, obſervable in each 25 hours; and that theſe ſpring tides, which are once a month upon the new and full Moons, are occaſioned by the attractive force of the Sun, in the new and full, conſpiring with the attraction of the Moon, and producing a tide by their united forces; whereas, in the quarters, the Sun raiſes the water where the Moon depreſſes it, and the contrary, ſo as the tides are only by the difference of their attractions; and that the force of the Sun, is no greater in this caſe, proceeds from the very ſmall proportion the ſemidiameter of the Earth bears to the vaſt diſtance of the Sun.

And as to theſe two annual ſpring tides, that are at the Equinoctial in March and September, or near them, are the higheſt, and neap tides the loweſt, it proceeds from the greater agitation of the waters, when the fluid ſpheroid revolves about a greater circle of the Earth, than when it turns about a leſſer circle. And the reaſon why the very higheſt ſpring tides are found to be before the vernal, and after the autumnal Equinox, viz. in February and October, rather than upon them is, becauſe the Sun is nearer

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the Earth in the winter months, and ſo comes to have the greater effect in producing the tides.

As to this we obſerve, that obſervations teſtify as to the general order of tides, that they make their revolution to the weſtward diurnally, according to the courſe of the Moon, and keep very near under her Meridian, except where intervening continents are in the way. And that the ſpring tides are not on the new and full Moons, but generally they are the third tides after them. And that alſo the two annual, and very higheſt ſpring tides, are produced before the vernal, and after the autumnal Equinox, in the months of February and October. As to the firſt ſort of theſe floods, the Moon is a more immediate ſign as to the time of their diurnal revolution. But as for the monthly and and annual higheſt floods; the Sun and Moon are not ſo immediate ſigns. And if the Sun and Moon were the ſole and only operative cauſe of tides, then it might be expected, according to human reaſon, that they would be as immediate ſigns of theſe monthly or annual high tides as of the others.

Plate 13. Fig. 2. Of tides.

For in figure 2d, let MR be any Meridian of the Sun or Moon, it is there plain from inſpection, that the ocean is more open for the water to uſher in from the Poles to the Equinoctial, againſt the time of the new or full Moons, than it is for the tides to make their way in their revolution round about from eaſt to weſt. For the continents of the Earth extend and ſtretch much further out from north to ſouth than they do from eaſt to weſt; and their natural ſituation tends more to interpoſe againſt the way of the regular motion of the water from eaſt to weſt, than they do againſt the waters flowing in from the Poles to-

wards the Equinox. And although the Moon proceeds gradually in her courſe to the new and full Moons, at or near the Equinoxes, yet the high floods are generally three tides afterwards; whereas it might be expected that theſe high floods would keep as near the time of the new and full Moons, as the diurnal tides keep under her Meridian, if all depended entirely upon the Sun and Moon's attraction.

And if theſe very higheſt ſpring tides, which are found before the vernal, and after the autumnal Equinox, in the months of February and October, made their appearance then, rather than in the months of March and September, and were produced merely becauſe the Sun is nearer the Earth in the winter months than in ſummer, this nearer approach of the Sun might naturally be expected to produce the very higheſt tides, during the time of the winter months, at the time of the new and full Moons, which obſervation, and experience, ſhews is not the caſe.

We ſee from what hath been formerly ſaid, and repreſented, that the water of the ſea itſelf is endowed with a principle of motion, as well as the inanimate matter of the bodies of the Sun and Moon are. And in conſequence of that connection, in the works of nature, they co-operate with the ſea in theſe revolutions, and they are either more immediate, or a little more remote ſigns and manifeſt tokens, of theſe tides that are ordinary, or of thoſe higher floods that are more ſingular in their approach. And it is to the different poſitions of theſe two luminaries in the Heavens, that we muſt have recourſe in our calculations, both as to the time and quantity of the different tides.

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Thus we have given a deſcription of the tides that they are to be underſtood as making one remove circularly from eaſt to weſt in 24 hours and 48 minutes. And the various other librations and motions, which are directed in different poſitions, they all proceed and flow from this being occaſioned from intervening continents of the Earth, that obſtruct its general courſe; and the different forms of the bays, creeks, ſhores, ſtraights, and ſeas, through which this general revolution paſſes. And the ſea, as has been ſaid, is underſtood in a ſmall degree, as compoſed in the form of an oblong ſphere, ſeveral feet of meaſure more in length than breadth, which makes one circular revolution to produce two tides in the ocean each day. And the different poſitions of the Sun and Moon, in the Firmament of Heaven, give manifeſt tokens and ſigns of this to mankind. And by that connection and ſequence that is among the works of nature, and among the manifold uſe and ſervice which the Earth receives from the Sun and Moon, they in their courſes, and attractive influences, concur with, and accelerate this operation. And all this proceeds from the wiſe deſignation of things, the laws given to inanimate matter and bodies, and the powerful overruling, diſpoſing and governing providence of God.

And not only the tides themſelves make the motions and librations of the Sea, but the winds alſo make currents and various evolutions upon it. The very high winds that blow from the ſouth-weſt, and that come off the Mardelzur Sea, by the point of Cape Horn, in South America; and even thoſe that blow over the Mexican mountains, make ſometimes currents in the Atlantic ocean, along the eaſt coaſt of America. And when theſe happen to be mixed with north-

west winds, this sometimes makes a turn of the current to the south, beyond the west coast of Africa. And high winds that blow from the south-west of the Ethiopic ocean, by Cape Bona, on the south of Africa, sometimes make currents that move eastward, by the south of Madagascar, in the Eastern ocean. And in a word, when great winds blow upon any part of the sea whatever, they cause a kind of current upon the surface, or upper part of the Sea, which is directed that way which the wind blows. And besides these, when boisterous winds chance to blow upon the Sea from distant and different quarters, and where they come to meet these at some times and places, cause a kind of wheeling, or vertiginous motion upon the Sea, which is very dangerous for shipping and seafaring men, that are driven by the winds, or drawn by the currents near to these vertiginous places of the sea. And ships have been observed to be overturned and sunk either by the wheeling motion of the currents or the winds, in those places: at some times these, by seafaring men, are called inlets, or sources of the Sea.

We had under our consideration, and treated a little of the general fabric and Firmament of the higher region of the material Heavens, within whose circumference all those motions of material things are contained; and have spoken of these in the Firmament of the air, and lower region of Heaven, such as fiery meteors, winds, clouds, rain, snow and hail, mist and dew. And these on the surface of the earth and sea, as exhalations, earthquakes, fountains, streams and rivers on the Earth; and the evolutions in the ebbing and flowing of the Sea.

These descriptions we have given, and the demon-

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And after the moſt mature contemplation upon their natural courſe, that can be taken by the human mind of man, we muſt after all this, acknowledge with the profoundeſt deference and reſpect, that it is God only who knows all theſe things fully and perfectly.

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Shewing that there is an immediate interpoſition in, and over all the works of nature.

AS to that notion of the divine works, which ſuppoſes that it is eſſential to the perfection of them, that there ſhould be no divine immediate interpoſition of any kind, not even for the moſt important purpoſes; and that there is a certain concatenation of cauſes and effects in the elements and bodies of the world themſelves, for the production of the various phenomena and appearances in nature, according to the general eſtabliſhed laws of matter.

We ought indeed to admire the divine power, and wisdom, and other perfections manifested in the established laws of nature, from which so glorious an order results. But the excellence of these divine operations, which may be supposed to be merely according to these laws, and the order that results from them, receives no prejudice from a mixture of other operations of a different kind, which do not reverse these laws, but promote the highest ends of them. To suppose that the first cause must produce no effects but what second causes are sufficient to produce by the power he has given them, by general established laws of nature, is a supposition of bad influence. It is exceeding unsuitable to the impressions we should have of the incomprehensibility of God and his works. It tends to lessen our ideas of the influence of providence, and has too much affinity to the old heathen fate. It tends to lessen moral dependence of reasonable creatures on the Deity, and to lessen our apprehension of that moral order of the world which is of supreme importance, and to which the natural is subservient. This opinion is founded partly on mistaken notions of supernatural operation, and partly on wrong suppositions, against which there are strong exceptions from natural reason, though we should abstract from Revelation.

And this notion, when taken in its full latitude, clashes with the known observation of the best philosophical enquiry on the laws, and chief known parts of the frame of nature; namely, that tho' they are calculated for a very long continuance, yet not for a perpetual continuance, without renewed divine interposition. The ever glorious and eternal Deity, who being ever essentially perfect in himself from all eter-

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nity, did in time, make the world out of nothing, or gave a being to that which had no being before; and fixed certain general laws upon the elements and bodies of the world as to motion or reſt. And it is on him that they depend both for the preſervation of their exiſtence and continuance, in their different ſtructures and movements. For it is a moſt certain principle in reaſon, that as the world could not ariſe out of nothing unto a ſtate of exiſtence, without the Deity's creating power; ſo neither can it continue in a ſtate of exiſtence, but by the vigilance of the ſame power by which it was made. And this power is abſolutely neceſſary every moment, for the conſervation of the world, as well as it was neceſſary for its creation. For that which would never have come into being of itſelf, could never by itſelf preſerve its own being. And as the making of matter out of nothing is poſſible, it is altogether as poſſible that matter might be reduced to nothing. And according to ſacred hiſtory and chronology, the number of 6000 years has not yet elapſed ſince the world was made out of nothing. And alſo ſacred writ makes known, and fully aſcertains, that the material ſyſtem is to undergo a final tranſmutation and change; and therefore, that which comes to paſs at any time, might likewiſe in the grand oeconomy of things come to paſs at every time. It depended upon the divine power, to bring the world into being, at the time of its firſt ſtate of exiſtence; and it entirely depends upon the will of the Deity, as to the time of its continuance as to its preſent uſe, and period of its final exit, or tranſmutation and change.

But further, as to the motions in the material world, when it is ſuppoſed that all of them without exception happen merely according to general laws,

this ſeems partly owing to inadvertence. It is true, there is a viſible conſtancy and uniformity in moſt of theſe things, particularly in the motions of the heavenly bodies, and what has a connexion with it; but it is not ſo with reſpect to all and every one of them. For there are Stars that have appeared at certain times, and again at different periods have diſappeared from open view. And of the catalogue of Stars, marked by ancient Aſtronomers, ſeveral of them are now no more to be ſeen in the Firmament of Heaven. And likewiſe as to the Comets, although ſome Aſtronomers have computed the motions of ſeveral Comets and compared them with the obſervations made by others, and have found that there was a near correſpondence between them; yet when all things concerning the Comets are taken together, ſuch as their proper magnitude, the brightneſs of their appearance, the length and breadth of their tails, the velocity and rapidity of their motions, the period between their appearances and the time that they continue in open view; theſe things, when compared together, they cannot be found in exact uniformity in the Comets; which ſhews that there is a certain variety in this phenomena of nature. And there are to be ſeen in the body of the Sun, and ſeveral of the Planets, ſpots of aſſemblages of condenſed matter, that ſometimes appear, and afterwards diſappear, more or fewer at a time: of all which, there is not to be found an exact period of the preciſe time of their diſappearings and returns.

And it is ſtill further obvious, that there is another part of the viſible creation on which the uſefulneſs of the other parts of it to its inhabitants very much depends, in whoſe motions there is ſo vaſt a variety of

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changes, that no uniformity can be discerned or pretended, nor any general laws by which they can be for the most part accounted for; and that is the motions of the air in which we breathe. The motions of the air are of great importance to mankind, and other creatures; that without them the regular variety of seasons would be useless, and all the provision for the life of the animal world lost. As these motions are ordinarily the means of innumerable advantages, they are capable of being the instrument of various calamities; such as famine, pestilence, and epidemic diseases; besides various particular disasters. The thing that makes them capable of answering so many different ends, is their inconstancy and variety: these are things which no philosophy can reduce to general laws.

Now, that some indeed have supposed that infinite wisdom may have so contrived the frame of nature, that all these motions, however various, should owe their rise to natural causes, without any divine interposition. In answer to this, we observe, that they can bring no positive proof for it; tho' we must acknowledge, that nothing in the course of nature is impossible unto infinite wisdom and power. And it is sufficient to our present purpose to observe, that it is altogether possible and very apparently otherwise. The incomprehensibility and omnipresence of God, the care he has of his own works, his divine purposes, and the execution of these purposes, and the many and various manifestations which he has given of his power in his working with ordinary means, or without means, and also above the power of nature, yea, and even contrary to the ordinary course of nature, are all proofs of the immediate divine interposition in, and over his works. Many instances of which, we have in the miracles that have been wrought in binding of

the laws, and turning the ordinary courſe of nature out of its proper channel. Such as the miracles wrought for and by Moſes, as it was in the deſert of Horeb, when the buſh burned with fire, and yet the buſh was not conſumed by the fire. And of Moſes' rod, or ſtaff in his hand, when it became a ſerpent; and of a ſerpent it became a rod in his hand again. And alſo of the ſtreams, rivers, and ponds, in the land of Egypt, that from water were turned into, and became blood, throughout all the land. Likewiſe alſo, there was a ſupernatural change wrought in the air, as well as in the water; for there was a perfect and total darkneſs cauſed in the land of Egypt for the ſpace of three days, to the Egyptian inhabitants. And that which made it ſtill the more remarkable, the Iſraelites, whoſe habitations were very near adjoining theirs, had light in their dwellings. As alſo the dividing of the waters of the Red Sea, when the children of Iſrael went into the midſt of the Sea upon the dry ground; and during the time of their paſſing through, the waters were a wall unto them on their right hand, and on their left. But when the Egyptians attempted the taking of the ſame paſſage, they were drowned. Likewiſe, the ſtopping of the ſtream, and drying up of the waters of the river Jordan, in the time of its high flood, until the Iſraelites paſſed over. And the preſerving alive of theſe three men of the children of Judah, when they were caſt into the midſt of the Babylonian burning fiery furnace, upon whoſe bodies the fire had no power, nor was an hair of their head ſinged. Theſe are a few of the many and innumerable inſtances of the divine interpoſition in changing the ordinary courſe of nature in its cauſes and effects, which were wrought upon all the four different elements of the earth, air, fire, and water. And not

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only on theſe, but alſo there was an immediate divine interpoſition with reſpect to the heavenly bodies, in ſtopping the motion of the Sun and Moon, in their courſe, in the firmament of Heaven, at the earneſt requeſt of Joſhua. As alſo the Sun returned ten degrees backward, by which degrees he was gone down, to be for a ſign to the king Hezekiah in his ſickneſs.

Add to all theſe, the many miracles that were wrought by our bleſſed Saviour when on earth, which are infallible evidences of the divine interpoſition upon the ſtate and courſe of nature. But philoſophy itſelf is at a loſs here to demonſtrate how far the divine interpoſition ſuperintends and precides over the world. But what men are at a loſs with, Chriſt Jeſus, who knew all things, condeſcended to demonſtrate to us how far the divine providence pervades through, and preſides over created nature, even unto the moſt ſmall and minute things in it. For, ſays he, "Are not "two ſparrows ſold for a farthing, and one of them "ſhall not fall to the ground without your Father— "and the very hairs of your head are all numbred." The manifeſtations and diſplays of the divine providence are all and ever glorious and excellent in themſelves. And this ſhews to us the divine cogniſance of all his works, and that not only of the greateſt of them, but alſo of the very leaſt of them likewiſe: none of them are below his knowledge and care. And further, we obſerve from the words of our bleſſed Saviour here, that they are ſpoke in the preſent tenſe, which ſhews divine providence to be ever and anon with, and over all things.

Hence we ſee, that the being and exiſtence of all created nature or things, depends on the will and the power of the Deity; and that the bodies of the world, which are under uniform eſtabliſhed laws, as to their

motion or reſt, receive theſe laws, or, as it may be truly and more fully expreſſed, they continually need and receive from the Deity, an executive power to keep an exact and perpetual order and decorum in their motion, or reſt. And likewiſe, as to theſe more irregular or tranſient motions of the Elements, or bodies in the world, are not reduced under a permanent and uniform operation in it; all and every one of theſe moſt contingent and caſual motions or operations, come by and through the divine direction or permiſſion, are under his conduct and management, and liable to his reſtriction and control. And this muſt neceſſarily be in the nature of things concerning all inanimate matter and bodies; for lifeleſs inanimate matter cannot move itſelf, neither can it move any other matter beſides itſelf, therefore there muſt be a firſt mover. But in vain ſhall we ſearch through the regions of ſpace, amongſt the ſyſtem of created beings for this; for if we did, all of them would give us the diſappointment. Should we in our enquiries on this, fix our thoughts upon the Earth, or the Sun, as the common operator and firſt mover of the univerſe of matter and bodies, becauſe theſe are the two moſt remarkable bodies in the ſyſtem of matter, by either the one or the other of them, we would be deceived and diſappointed. For neither the Earth nor the Sun can move of and by themſelves, no more than any other of the ſeveral parts of inanimate matter, and therefore they cannot move other bodies. For tho' the body of the Sun be moved, and there are an innumerable variety of different motions upon the body of the Earth, yet the firſt cauſe of theſe motions are not in and of themſelves, they being but lifeleſs inanimate matter, without mind, wiſdom and direction.

This moſt excellent and admirable work, proceeds

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from, and is to be afcribed unto the Eternal Deity, who made and upholdeth all things by the word of his power. And although a fmall part of the concatenation of fecond caufes is conceivable by the human mind, how feveral of the Elements and bodies move and operate; yet how the whole frame and fyftem of the world ftands fupported, and how the whole has a connexion with, and promotes the good of every particular part, and how every particular part is relative to, and fubfervient for the good of the whole, or if the whole fyftem of bodies has a phyfical and mutual dependence upon one another, are propofitions, which the finite mind cannot fully comprehend, and human reafon fufficiently demonftrate. As the mind is, fo is the underftanding: finite minds are not fully adapted to comprehend the productions of an infinite caufe; and human reafon cannot perfectly define or demonftrate the works of Omnipotence. The divine works can no further be underftood than as they are in the level with the fphere of reafon, as to their nature or phyfical operations and motions; and as far as they are fuch, they are conceivable by the human mind. And the way and manner, how the nature or operation and motion of the Elements and bodies of the world comes to be conceivable and underftood by the human mind, is by the means of the fenfes, implanted in the human body, as they are directed and governed by reafon. And ftill further, as to the knowledge of the operation, and efpecially as to the reft and motion of the more permanent bodies of the univerfe, as it ftands corroborated and confirmed by the revelations that are from the Deity himfelf, the bodily fenfes governed by reafon, and corroborated by divine revelation, is the only certain criterion for coming to the knowledge of the reft or motion of thefe great and permanent bodies in the great phenomena of nature.

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permanent before in the great continent of